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SATURN S-IVB MATERIALS AND PROCESS DEVELOPMENT REPORT (JUNE 1963 - DECEMBER 1963)

(U)

JANUARY 1964
ISSUE NO 2
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Semiannual Summary Report

ABSTRACT

This report is a summary of material and process development work done by Douglas Aircraft Company as a part of the Saturn S-IVB program from 1 June 1963 to 1 December 1963. The report contains a description of work initiated during this report period as well as new data concerning work not completed during the last report period. Progress was made in the evaluation and development of (1) non-processed and processed materials designated for specific S-IVB applications, (2) production processes and process improvements, and (3) protective packaging.

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Section I

INTRODUCTION

1.1 PURPOSE

This is the second Saturn S-IVB Materials and Process Development Report compiled in accordance with contractual requirements for a semiannual summary report covering work done by Douglas Aircraft Company in the area of material and process development pertaining to the Saturn S-IVB.

1.2 SCOPE

Information is presented within the report concerning work performed toward the development of processing materials, processes, and protective packaging for the Saturn S-IVB during the period from 1 June 1963 to 1 December 1963.

1.3 PLAN OF REPORT

Each topic contained in the report is presented as an entity. Topics are grouped with respect to the particular area of materials and process development, i.e., non-processed materials (Section II), processed materials (Section III), process development (Section IV), and protective packaging (Section V). Illustrative matter and conclusions are presented at the end of each topic when the nature and status of the work so warrants.

1.4 SUMMARY OF REPORT

A summary statement covering each topic discussed in Sections II through V is presented in Table I - I for convenience.

TABLE I - I

SUMMARY STATEMENT

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SECTION II

STUDY AND DEVELOPMENT OF NON - PROCESSED MATERIALS

Studies conducted to evaluate non-processed materials for use in the Saturn S-IVB are summarized in this section.

2.1.3 Test Results

The results of tensile testing are listed in table 2-2. The ultimate tensile strength (Ftu) and ductility (per cent elongation) decreased as distance from the end chill increased. A pronounced change in the rate of decrease was noted approximately 8 inches from the end chill.

Complete reversal fatigue strength test results are listed in table 2-3. The complete reversal fatigue strength decreased as distance from the end chill increased. The rate of decrease was most pronounced at distances greater than 8 inches from the end chill.

The specimen plates from which the test coupons were taken all showed a progressive increase in radiographically visible discontinuities as distance from the end chill increased.

2.1.4 Conclusions

The decrease in complete reversal fatigue strength is apparently related to the decrease in ultimate tensile strength. The pronounced change in rate of decrease apparently results from a change in the solidification pattern at approximately 8 inches from the end chill. The pronounced reduction in complete reversal fatigue strength occurs after the metal has remained at or above the eutectic (1065°F) for, roughly, 300 seconds during the progressive solidification process (see table 2-4).

TABLE 2–1

COMPOSITION OF A356-T6 FATIGUE STRENGTH TEST COUPONS*

ELEMENT	COMPOSITION (PER CENT)
SILICON	6.9
MAGNESIUM	.47
TITANIUM	.20
IRON	.13
BERYLLIUM	.05
ALUMINUM	REMAINDER

*DETERMINED BY SPECTROGRAPHIC ANALYSIS

TABLE 2–2
TENSILE PROPERTIES OF A356-T6 CAST ALUMINUM AT VARIOUS DISTANCES FROM THE END CHILL

DISTANCE FROM CHILL (INCHES)	PLATE B COUPONS			PLATE E COUPONS		
	FTU* (KSI)	FTY* (KSI)	ELONGATION** (%)	FTU* (KSI)	FTY* (KSI)	ELONGATION** (%)
0.5	50.6	36.7	13.5	49.7	35.2	15.0
1.0	50.4	37.3	12.5	48.8	35.8	11.0
1.5	48.8	36.0	11.0	49.5	36.1	10.0
2.0	49.3	36.6	10.0	-----	-----	-----
2.5	-----	-----	-----	47.9	34.1	9.0
3.5	-----	-----	-----	47.1	34.7	8.0
4.0	47.0	35.9	6.0	-----	-----	-----
5.5	-----	-----	-----	44.6	34.2	4.5
6.0	45.5	35.5	4.0	-----	-----	-----
7.5	-----	-----	-----	42.2	34.2	2.5
8.0	43.3	35.0	3.5	-----	-----	-----
9.5	-----	-----	-----	34.1	30.8	1.0
10.0	37.4	32.9	1.0	-----	-----	-----
10.5	-----	-----	-----	35.2	31.8	1.0
11.0	34.5	33.7	0.5			

* FTU = ULTIMATE TENSILE STRENGTH
FTY = YIELD STRENGTH; 0.2 PER CENT OFFSET
** MEASURED BY FIT-BACK, GAGE LENGTH = 2 INCHES

TABLE 2-3
COMPLETE REVERSAL FATIGUE STRENGTH OF CAST A356-T6 ALLOY AT VARIOUS DISTANCES FROM THE END CHILL

DISTANCE FROM CHILL (INCHES)	PLATE	MAXIMUM STRESS (KSI)	MEAN ULTIMATE STRENGTH (%)	CYCLES TO FAILURE
0.5	J	35.0	70.0	6,500
	G	30.0	60.0	26,800
	C	25.0	50.0	38,850
	D	25.0	50.0	86,300
	H	20.0	40.0	279,150
	A	20.0	40.0	223,400
	F	15.0	30.0	1,064,500
1.0	I	35.0	70.4	5,300
	G	30.0	60.4	30,800
	D	27.5	55.3	53,400
	J	22.5	47.3	152,500
	F	17.5	35.2	243,400
1.5	H	17.5	35.5	389,400
	G	17.5	35.5	217,700
2.0	I	35.0	71.4	4,800
	C	27.5	56.1	55,500
	H	25.0	51.0	59,300
	F	22.5	46.0	121,300
	E	20.0	40.8	174,400
	D	17.5	35.7	539,400
	G	15.0	30.6	419,000
3.0	H	35.0	72.8	3,200
	I	35.0	72.8	2,400
	C	30.0	62.4	29,450
	F	27.5	57.2	43,000
	A	25.0	52.0	51,400
	E	22.5	46.8	129,200
	J	20.0	41.6	140,400
	B	17.5	36.4	169,200
	D	15.0	31.2	381,700
	G	15.0	31.2	332,700
3.5	I	25.0	52.5	32,000
	F	22.5	47.2	91,400
	D	20.0	42.1	153,800
	H	17.5	34.6	432,700

TABLE 2–3 (CON'T)

DISTANCE FROM CHILL (INCHES)	PLATE	MAXIMUM STRESS (KSI)	MEAN ULTIMATE STRENGTH (%)	CYCLES TO FAILURE
4.0	A	15.0	31.7	319,700
4.5	I	35.0	74.9	2,200
	E	30.0	64.8	13,000
	D	27.5	58.7	19,400
	G	25.0	53.4	28,900
	B	22.5	48.7	72,500
	J	20.0	42.8	108,900
	H	17.5	37.5	234,800
5.0	I	35.0	75.8	1,100
	J	30.0	65.0	8,200
	E	25.0	56.3	35,250
	H	22.5	48.0	47,000
	C	20.0	43.3	114,800
	A	17.5	37.9	110,500
	B	15.0	32.5	322,700
6.5	B	35.0	78.7	2,100
	F	30.0	67.4	7,000
	J	25.0	56.2	26,100
	H	22.5	50.5	34,300
	C	20.0	44.9	57,800
	A	17.5	39.3	221,900
	G	15.0	33.7	169,000
8.0	I	35.0	82.9	600
	H	30.0	71.0	2,400
	F	25.0	59.2	9,200
	D	25.0	59.2	23,400
	A	22.5	53.3	27,450
	C	20.0	47.4	60,000
	J	17.5	41.5	129,800
	G	15.0	35.5	129,000
8.5	A	35.0	85.0	350
	D	30.0	72.8	2,600
	B	27.5	66.7	8,200
	E	22.5	54.6	9,100
	G	20.0	48.5	37,900
	C	17.5	42.5	87,700
	H	15.0	36.4	204,500
	I	12.5	30.3	604,800

TABLE 2-3 (CON'T)

DISTANCE FROM CHILL (INCHES)	PLATE	MAXIMUM STRESS (KSI)	MEAN ULTIMATE STRENGTH (%)	CYCLES TO FAILURE
9.0	D	35.0	87.5	400
	G	35.0	87.5	100
	C	30.0	75.0	1,700
	I	27.5	68.75	2,000
	F	25.0	62.5	13,000
	H	22.5	56.25	11,500
	E	20.0	50.0	37,200
	A	17.5	43.75	80,600
	J	15.0	37.5	199,700
	B	12.5	31.25	159,800
9.5	C	35.0	90.2	150
	D	30.0	77.3	1,650
	B	25.0	64.4	5,300
	I	22.5	58.0	11,000
	H	17.5	45.1	51,600
	F	15.0	38.6	132,000
10.0	I	35.0	93.3	50
	C	30.0	80.0	100
	H	27.5	73.3	700
	A	25.0	66.6	3,500
	D	22.5	60.0	11,800
	E	20.0	53.3	10,900
	F	17.5	46.7	68,700
	G	17.5	46.7	47,400
	J	15.0	40.0	81,100
10.5	F	30.0	82.6	300
	H	25.0	68.8	2,100
	C	22.5	62.0	1,200
	G	20.0	55.1	11,600
	B	17.5	48.2	69,900
	D	15.0	31.3	82,500
11.0	H	35.0	100.0	-----
	C	30.0	85.7	100
	G	25.0	71.4	2,700
	A	22.5	64.3	8,450
	I	20.0	57.0	18,900
	J	17.5	50.0	43,500
	F	15.0	42.8	96,700

TABLE 2–4
EFFECT OF COOLING RATE ON COMPLETE REVERSAL FATIGUE STRENGTH
OF A356-T6 ALUMINUM ALLOY

COUPON GROUP	DISTANCE FROM CHILL (INCHES)	MEAN TIME TO REACH 1065° F (IN SECONDS)	TIME REMAINING AT 1065°F (IN SECONDS)	CHANGE IN STRENGTH PER LOG CYCLES	
				PSI	PER CENT
I	0.5 TO 2.0	30	0	−962	−19.3
II	3.0 TO 4.5	175	10	−907	−19.3
III	5.0 TO 6.5	230	40	−889	−19.6
IV	8.0 TO 9.0	230	100	−706	−17.4
V	9.5 TO 11.5	230	190	−569	−15.4

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SECTION III

STUDY AND DEVELOPMENT OF PROCESSED MATERIALS

This section contains a summary of investigation and tests performed to develop processed materials for use in the Saturn S-IVB program during the current report period.

3.1 EVALUATION OF NEW HIGH PEEL ADHESIVES FOR BONDING THE COMMON BULKHEAD

The adhesive systems presently used for bonding the common bulkhead of the Saturn S-IV are HT 424/HT 424B epoxy-phenolic (made by Bloomingdale Rubber Company) and Lefkoweld 109/LM 52 modified epoxy (Lefkoweld Chemical Co.). Although these adhesives are capable of functioning at cryogenic temperatures, it is desirable to find an adhesive with greater peel strength for use in bonding cryogenic areas of the Saturn S-IVB common bulkhead. An evaluation program was initiated during the last report period (see issue number one of this report) in order to study the bonding characteristics of several new, commercially available adhesive systems (see Table 3-1).

3.1.1 Approach

The work was divided into two phases. Phase I consisted of tests designed to eliminate all but the most suitable materials. Phase II consisted of comparison testing of the most suitable materials with HT 424/HT 424B and Lefkoweld 109/LM 52.

3.1.2 Phase I Evaluation

Two types of adhesive systems were selected for Phase I testing:

a. Room temperature (RT) curing, two component pastes

b. Structural adhesive films having a maximum cure temperature of 350°F

The materials selected and the manufacturers are listed in Table 3-1.

Specimens of each of the RT curing pastes were subjected to the following tests:

a. Tensile shear (2024-T6 clad aluminum sheet)

b. T-peel (2024-T6 clad aluminum sheet)

c. Tensile strength (one inch diameter, cylindrical aluminum buttons)

Specimens of the 350°F curing adhesive films were subjected to the following tests:

a. Tensile shear (2024-T6 aluminum sheet)

b. T-peel (2024-T6 aluminum sheet)

c. Tensile strength (one inch diameter, cylindrical aluminum buttons)

d. Thermal shock (aluminum and Teflon, TFE, bondized)

e. Climbing drum peel (2024-T6 aluminum, Heat Resistant Phenolic (HRP), and aluminum core)

3.1.2.1 Test Results

As a result of Phase I testing, the following adhesives were selected for Phase II comparison studies:

a. EC 2216 B/A modified epoxy adhesive paste system (RT curing)

b. Narmco 7343/7139 polyurethane adhesive paste system (RT curing)

c. AF 300 modified epoxy adhesive fabric (350°F maximum cure)

d. FM 1000 nylon-epoxy adhesive film (350°F maximum cure)

e. Metlbond 400 adhesive film (350°F maximum cure)

3.1.3 Phase II Evaluation

The RT curing pastes selected from Phase I were compared with Lefkoweld 109/LM 52 by the following tests:

a. Tensile shear (-423°F to +250°F)

b. T-peel (-423°F to +250°F)

c. Tension, sandwich specimens (-423°F to +250°F)

d. Creep and fatigue (-320°F and RT)

The 350°F curing adhesive films selected from Phase I were compared with HT 424/HT 424B by the following tests:

a. Tensile shear (-423°F to +250°F)

b. T-peel (-423°F to +250°F)

c. Tension on HRP core (-423°F to + 250°F)

d. Climbing drum peel (HRP and aluminum core)

e. Creep and fatigue (-320°F and RT)

f. Flexural shear (HRP core)

3.1.3.1 Curing of specimens

All of the adhesive films were cured in an autoclave with a pressure of 50 psi. The temperature was raised from ambient to 350°F in 30 minutes and held at that temperature for one hour. All of the pastes were cured for a minimum of three days at room temperature under a load of 2 1/2 pounds per square inch.

3.1.3.2 Test Procedures

Normal test procedures were followed whenever possible. A large diameter, vacuum jacketed test cryostat was fabricated for the evaluation of normal T-peel and climbing drum peel, using standard sized specimens.

Tensile shear tests were conducted in a Baldwin tensile testing machine, using a load rate of 1200 to 1400 pounds per minute until failure of the specimen occurred. T-peel specimens were pulled in a testing jig using a jaw separation rate of 20 to 24 inches per minute at RT and +250°F. At -423°F, the jaw separation rate was 5 1/2 inches per minute. Climbing drum peel tests were performed as outlined in MIL-A-25463. Tensile specimens were subjected to three temperature cycles, each consisting of 15 minutes at -65°F followed by 15 minutes at +160°F. Loss of adhesion was determined visually. Creep test specimens were loaded to 500 psi in a compression type, creep testing jig and tested at RT for 192 hours; -320F for 24 hours. Fatigue tests were performed under a load of 1800 psi using 1000 cycles per minute until failure. The sandwich tensile specimens were loaded in tension at the rate of 400 pounds per minute until failure. For RT flexural shear testing, the load was applied at midpoint over a six inch span at the rate of 1200 pounds per minute. At -423°F, the load was applied so that failure would occur in two to three minutes.

3.1.3.3 Phase II Results

The tensile shear, T-peel, and sandwich tension results at -423°F to +250°F, for the RT curing pastes in comparison with Lefkoweld 109/LM 52, are contained in Table 3-2. Figure 3-1 is a graphic comparison of tensile shear results. Results of creep and fatigue studies of the same materials are listed in Table 3-3. Tensile shear, T-peel, and HRP core tension results from -423°F to +250F, for the +350°F curing films in comparison with HT 424/HT 424B are contained in Table 3-4 (see also Figures 3-2 and 3-3). The results of climbing drum peel studies of the same adhesives on HRP and aluminum core are listed in Table 3-5. Results of creep and fatigue tests at room temperature and -320°F are listed in Table 3-6. Table 3-7 contains the results of flexural shear testing of sandwich specimens.

3.1.4 Conclusions

Narmco 7343/7139 room temperature curing, two component paste exhibited greater tensile shear, T-peel, tensile strength, sandwich tension, and resistance to thermal shock than Lefkoweld 109/LM 52 at cryogenic temperatures. Tensile shear and sandwich tension at room temperature were below the values for Lefkoweld 109/LM 52. The Narmco paste also exhibited more creep at both room temperature and -320°F. HT 424/HT 424B showed higher values than either AF 300 or FM 1000/BR 1009-49 for T-peel, core tension, and climbing drum peel at cryogenic temperatures. The tensile shear strength, however, was lower.

The results obtained with the 350°F curing films are based on an optimum cure temperature rise rate of approximately ten degrees per minute. The HT 424 film flows and cures at a lower temperature than FM 1000 and AF 300.

No further evaluation of adhesives for bonding the common bulkhead is contemplated at present.

TABLE 3-1
HIGH PEEL ADHESIVES FOR PHASE I TESTING

MATERIAL	TYPE	CURE	SOURCE
FM 1000/BR1009-49	FILM & PRIMER	350°F	BLOOMINGDALE RUBBER CO.
FM 96	FILM	350°F	
BR 86/XL-59-BR82	ADHESIVE SYSTEM	RT	
BR 92	PASTE	RT	
METLBOND 302	FILM	350°F	NARMCO MATERIALS CO.
METLBOND 400	FILM	350°F	
METLBOND 406	FILM	350°F	
NARMCO 3170	PASTE	RT	
NARMCO 7343/7139	PASTE	RT	
AF 40/EC1956	FILM	350°F	MINNESOTA MINING & MFG. CO.
AF 41/EC1956	FILM	350°F	
AF 300/EC2254	FABRIC & PRIMER	350°F	
EC 2216 B/A	PASTE	RT	
CRY-O	PASTE	RT	THERMO-RESIST CO.

TABLE 3-2
PROPERTIES OF RT CURING PASTES

TENSILE SHEAR IN PSI

TEMP °F	LEFKOWELD 109/LM52		EC2216 B/A		NARMCO 7343/7139		THIXOTROPIC 7343 (EXP)	
	SHEAR	FAILURE*	SHEAR	FAILURE*	SHEAR	FAILURE*	SHEAR	FAILURE*
-423	2,385	A	2,438	A	7,982	C	7,888	----
-320	2,675	A	2,740	A	7,157	C	7,844	A
-100	3,174	A	2,930	A	5,758	C	7,152	AC
RT	3,418	C	2,297	C	1,510	C	1,890	A
+180	368	C	580	C	386	A	488	A
+250	234	C	492	C	426	A	313	A

*A = ADHESIVE FAILURE
C = COHESIVE FAILURE

T-PEEL IN POUNDS PER INCH WIDTH

TEMP °F	LEFKOWELD 109/LM52		EC2216 B/A		NARMCO 7343/7139		THIXOTROPIC 7343 (EXP)	
	PEEL	FAILURE*	PEEL	FAILURE*	PEEL	FAILURE*	PEEL	FAILURE*
-423	3.6	A	6.2	70% C 30% A	80.4	AC	63.6	----
-320	3.0	--	2.0	--------	62.0	----	32.3	----
-100	3.1	C	2.6	C	32.2	A	21.9	A
RT	3.6	C	4.8	C	73.0	A	47.9	A
+180	2.4	C	4.7	AC	33.0	A	17.7	A
+250	2.9	C	3.0	C	16.3	A	13.2	----

*A = ADHESIVE FAILURE
C = COHESIVE FAILURE

TABLE 3-2 (CONT'D)

SANDWICH TENSION IN PSI-HRP CORE

TEMP °F	LEFKOWELD 109/LM52		EC2216 B/A		NARMCO 7343/7139	
	TENSION	FAILURE*	TENSION	FAILURE*	TENSION	FAILURE*
-423	189	AF	232	AF	423	F
-320	220	AF	282	AF	422	F
-100	275	AF	258	AF	382	F
RT	227	F	180	F	164	F
+180	94	F	62	AM	120	F
+250	38	AF	36	AM	67	90% AM 10% F

*AF = PARTIAL ADHESIVE FAILURE TO FOAM
F = FOAM
AM = ADHESIVE FAILURE TO METAL

COMPARISON OF TENSILE SHEAR OF ADHESIVE PASTES
AT VARIOUS TEMPERATURES

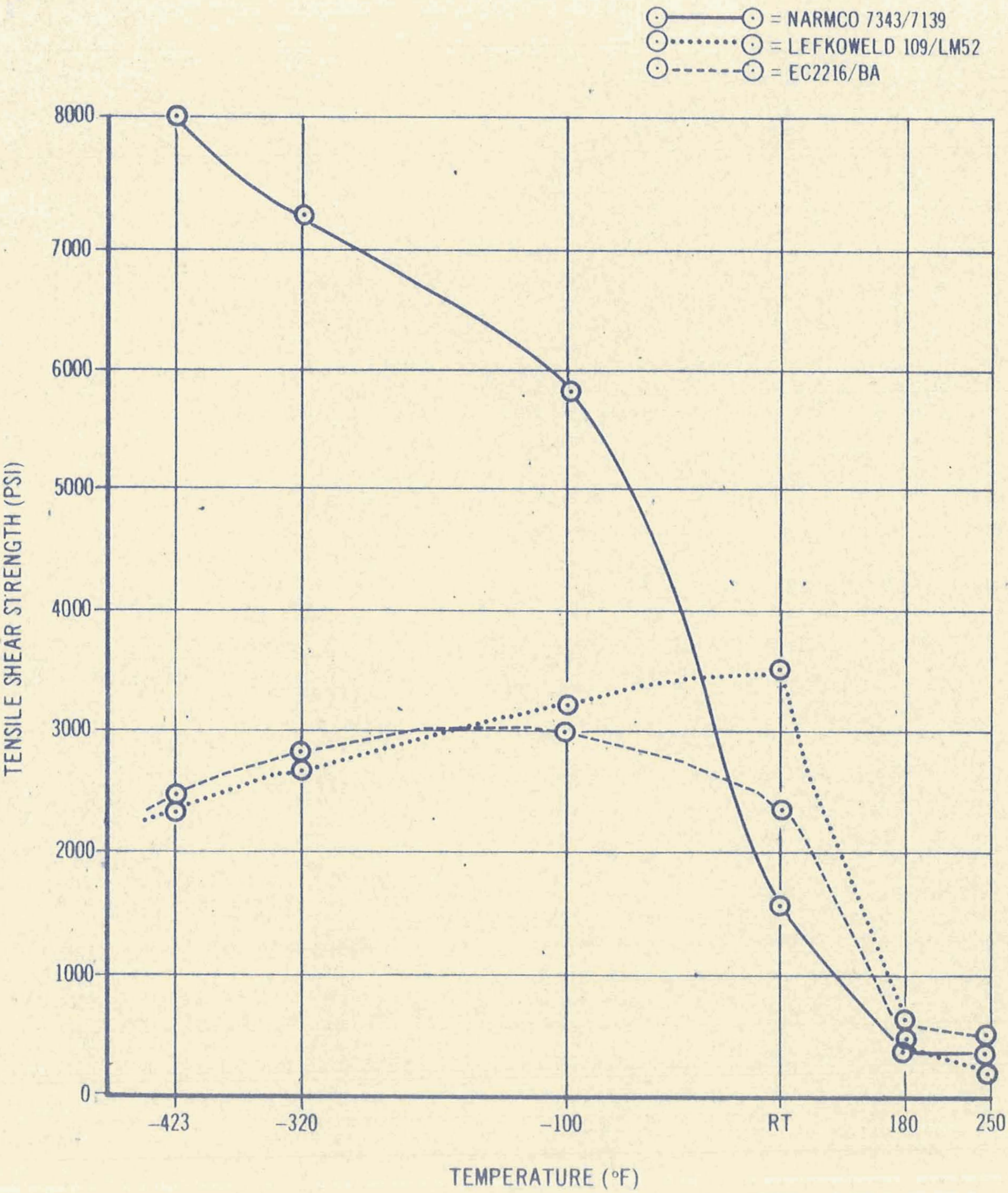


FIGURE 3-1

TABLE 3-3
CREEP AND FATIGUE IN RT CURING PASTES

ACTUAL CREEP IN INCHES*

ADHESIVE	TEMPERATURE (°F)	
	RT	-320
LEFKOWELD 109/LM52	3.4×10^{-6}	3.0×10^{-8}
EC2216 B/A	10.4×10^{-6}	2.5×10^{-8}
NARMCO 7343/7139	95.0×10^{-6}	12.8×10^{-8}

*500 PSI COMPRESSION

FATIGUE STRENGTH IN CYCLES TO FAILURE*

TEMP °F	LEFKOWELD 109/LM52		EC2216 B/A		NARMCO 7343/7139	
	VALUES	FAILURE	VALUES	FAILURE	VALUES	FAILURE
RT	2,940	BOND	150	BOND	-----------	WILL NOT
	3,850	BOND	300	BOND	-----------	SUPPORT 1,800
	4,200	BOND	400	BOND	-----------	PSI AT RT
-320	21,500	BOND	100	BOND	1,000,000	NONE
	---------	POOR ALIGNMENT	100	BOND	1,000,000	NONE
	604,100	ALUMINUM	200	BOND	1,000,000	NONE

*1,800 PSI – 1,000 CYCLES PER MINUTE

TABLE 3–4
PROPERTIES OF 350°F CURING FILMS

TENSILE SHEAR IN PSI

TEST TEMP °F	HT424/ HT424B		FM1000/ BR1008-49		AF300/ EC2254		AF300		METLBOND 400	
	SHEAR	FAILURE*	SHEAR	FAILURE*	SHEAR	FAILURE*	SHEAR	FAILURE*	SHEAR	FAILURE*
−423	2,758	C	3,628	C	6,110	C	6,742	----	6,540	A
−320	2,952	C	4,150	C	6,132	C	5,983	C**	6,562	A
−100	3,470	C	6,066	C	7,558	C	7,372	C	8,204	A
RT	2,887	C	4,921	C	5,480	C	5,036	C	6,566	A
+180	2,546	C	2,358	C	2,411	C	2,370	C	2,934	A
+250	1,906	C	1,341	C	1,431	C	1,441	C	1,790	A

*A = ADHESIVE FAILURE
C = COHESIVE FAILURE
**METAL FAILED – VALUE IS THAT OF REPULLED BOND

TABLE 3-4 (CONT'D)

T-PEEL IN POUNDS PER INCH WIDTH

TEST TEMP °F	HT424/ HT424B		FM1000/ BR1009-49		AF300/ EC2254		AF300 (.04 LBS/FT^2)		AF300/EC2254 (.08 LB/FT^2)		METLBOND 400	
	PEEL	FAILURE*	PEEL	FAILURE*	PEEL	FAILURE*	PEEL	FAILURE*	PEEL	FAILURE*	PEEL	FAILURE*
−423	16.7	C	4.1	AP	11.0	C	10.5	C	12.0	PM	----	---
−320	4.7	C	3.2	C	3.1	C	2.0	C	5.0	C	3.8	C
−100	7.7	C	7.8	C	5.3	C	4.5	C	8.7	C	3.2	C
RT	6.5	C	104.0	C	40.0	AC	42.0	C	170.0	AC	63.6	ERRATIC
+180	8.3	C	48.0	C	62.5	A	48.5	AP	76.0	PM	33.6	A
+250	8.1	C	12.1	C	28.9	C	21.9	C	23.0	C	11.6	C

* A = ADHESIVE FAILURE
C = COHESIVE FAILURE
AP = ADHESIVE TO PRIMER
PM = PRIMER TO METAL

TABLE 3–4 (CONT'D)

HRP CORE TENSION IN PSI*

TEST TEMP °F	HT424/ HT424B		FM1000/ BR1009-49		AF300/ EC2254		AF300	
	TENSION	FAILURE**	TENSION	FAILURE**	TENSION	FAILURE**	TENSION	FAILURE**
−423	1,306	C	293	CF	259	C	290	C
−320	1,219	C	492	30% C 70% HRP	354	C	369	C
−100	1,226	90% C 10% HRP	626	20% C 80% HRP	370	C	401	C
RT	743	90% C 10%HRP	277	CORE	333	90% C 10% HRP	446	C
+180	556	80% C 20% HRP	89	C-HRP	68	A	160	80% C 20% HRP
+250	543	C	49	C	56	A	68	C

*3/16 INCH CELL, 4 MIL CORE 1/2-INCH THICK

**A = ADHESIVE FAILURE
C = COHESIVE FAILURE
HRP = CORE FAILURE
CF = CORE TO FACING FAILURE

COMPARISON OF TENSILE SHEAR OF ADHESIVE
FILMS AT VARIOUS TEMPERATURES

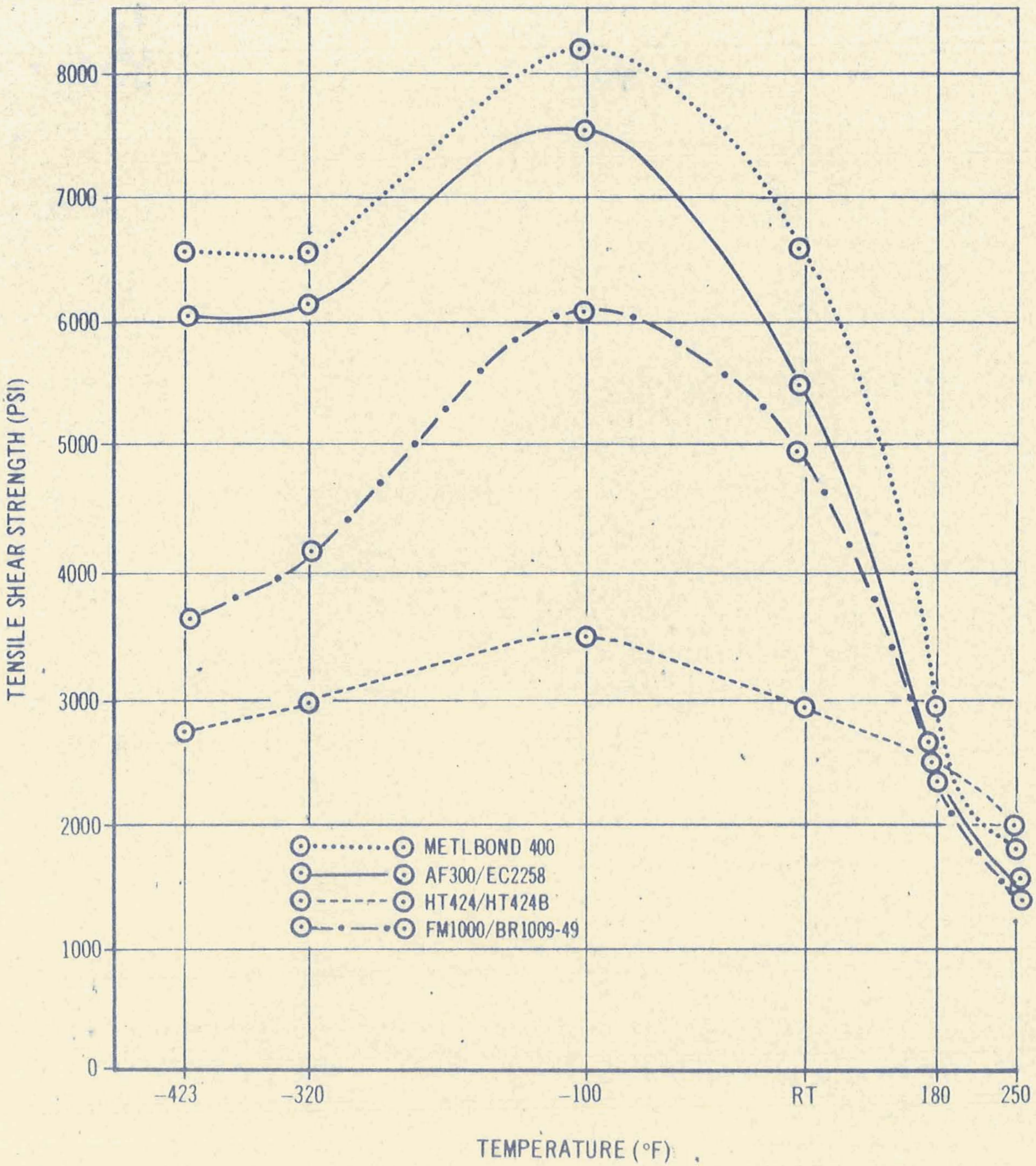


FIGURE 3-2

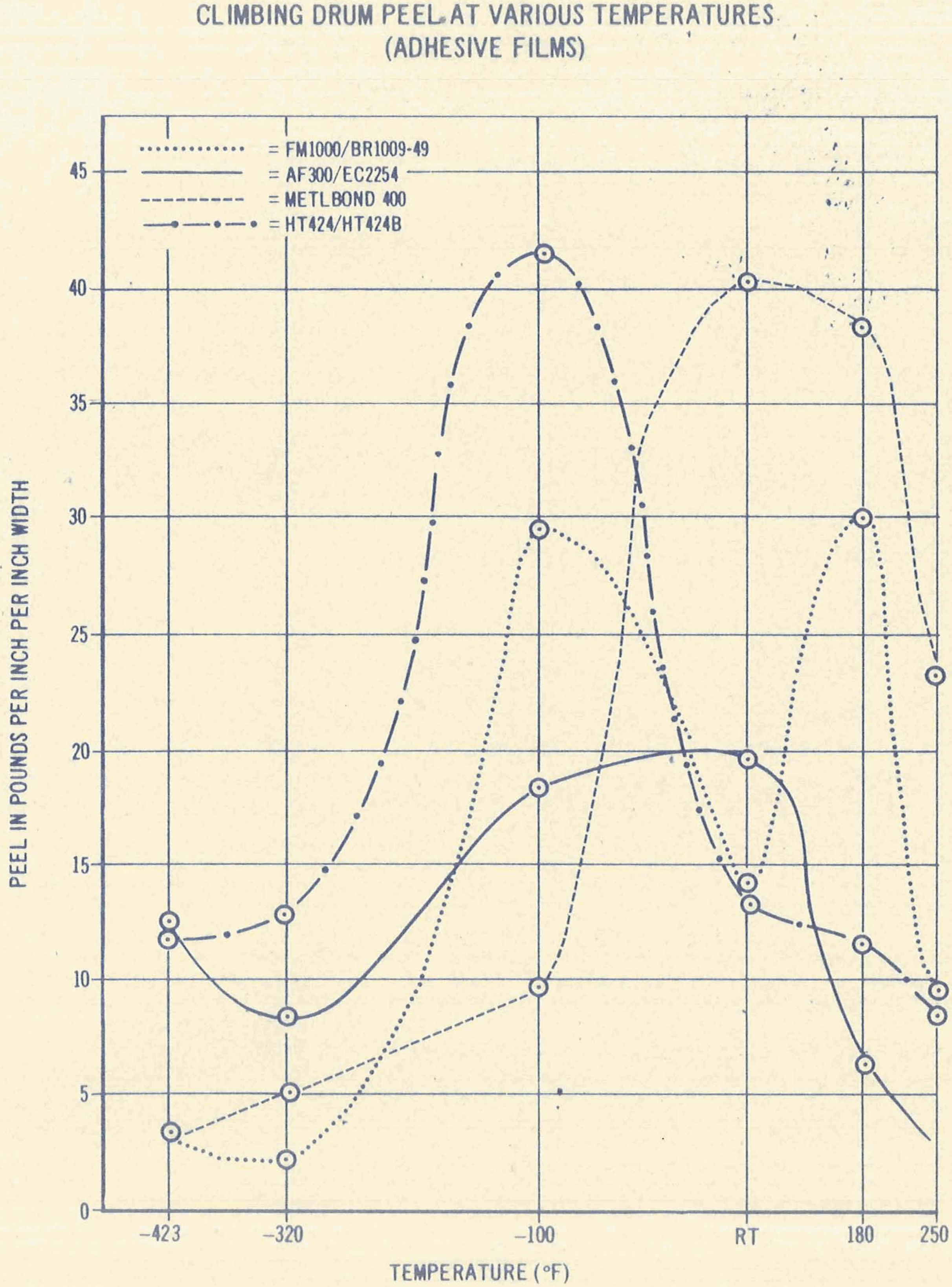

CLIMBING DRUM PEEL AT VARIOUS TEMPERATURES
(ADHESIVE FILMS)
= FM1000/BR1009-49
= AF300/EC2254
= METLBOND 400
= HT424/HT424B
PEEL IN POUNDS PER INCH PER INCH WIDTH
0
5
10
15
20
25
30
35
40
45
-423
-320
-100
RT
180
250
TEMPERATURE (°F)

FIGURE 3-3

TABLE 3–5
RESULTS OF CLIMBING DRUM PEEL STUDIES

HRP CORE PEEL IN POUNDS PER INCH – PER INCH WIDTH*

TEST TEMP °F	HT424/ HT424B		FM1000/ BR1009-49		AF300/ EC2254		AF300 (.04 LB/FT^2)		AF300/EC2254 (.08 LB/FT^2)		METLBOND 400	
	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**
–423	12.0	C	3.7	AM	12.6	HRP	6.8	AM	6.9	AM	3.4	MIXED
–320	12.9	C	2.5	PM	8.4	HRP	4.2	A	10.5	A	5.4	A
–100	41.5	C	29.3	80% HRP 20% A	18.4	HRP	10.1	A	26.1	HRP	9.8	A
RT	13.5	HRP	14.0	HRP	19.6	HRP	26.8	HRP	27.2	HRP	40.4	HRP
+180	11.6	C	34.0	MIXED	6.4	A	7.1	A	-----	-----	38.3	A
+250	8.6	C	9.8	C	2.3	A	4.2	A	-----	-----	23.3	A

*3/16 HRP, GF11; 4.0 LB; 1/2 INCH CORE

**A = ADHESIVE FAILURE
C = COHESIVE FAILURE
HRP = CORE FAILURE
AM = ADHESIVE TO METAL FAILURE
PM = PRIMER TO METAL FAILURE

TABLE 3–5 (CONT'D)

ALUMINUM CORE PEEL IN POUNDS PER INCH – PER INCH WIDTH*

TEST TEMP °F	HT424/HT424B (.17 LB/FT^2)		FM1000/BR1009-49 (.06 LB/FT^2)		AF300/EC2254 (.04 LB/FT^2)		AF300		METLBOND 400	
	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**	PEEL	FAILURE**
−423	18.6	C	5.9	PM	6.8	PM	3.1	AM	NONE	
−320	14.0	C	7.8	AP	7.8	----	5.0	----	11.3	A
−100	31.3	C	10.5	C	11.0	----	10.7	----	10.6	A*
RT	16.5	C	8.0	AI	12.3	----	9.9	----	116.0	A
+180	16.3	C	14.6	MIXED	11.2	----	9.1	----	37.4	A
+250	9.9	C	4.7	C	5.0	----	4.8	----	13.1	A

*5052; 3/16 INCH CELL; .0015P 3.4 DENSITY CORE

**A = ADHESIVE FAILURE
C = COHESIVE FAILURE
AI = CORE FAILURE
AM = ADHESIVE TO METAL
PM = PRIMER TO METAL
AP = ADHESIVE TO PRIMER

TABLE 3-6
CREEP AND FATIGUE IN 350°F CURING FILMS

ACTUAL CREEP IN INCHES*

ADHESIVE	TEMPERATURE	
	RT	−320°F
HT424/HT424B	10.2×10^{-6}	2.58×10^{-8}
FM1000/BR1009-49	2.6×10^{-6}	2.29×10^{-8}
AF300	4.1×10^{-6}	2.25×10^{-8}

*AVERAGE OF 3 SPECIMENS

FATIGUE STRENGTH IN CYCLES TO FAILURE*

TEST TEMP	HT424/ HT424B		FM1000/ BR1009-49		AF300/ EC2254	
	CYCLES	FAILURE	CYCLES	FAILURE	CYCLES	FAILURE
RT	4,550	BOND	186,250	METAL	268,800	METAL
	2,775	BOND	223,100	METAL	208,900	METAL
	4,900	BOND	254,400	METAL	282,400	METAL
−320	575,600	BOND	283,900	METAL	100,000,000	NONE
	516,350	BOND	211,200	METAL	100,000,000	NONE
	319,300	BOND	237,300	METAL	100,000,000	NONE

*1,800 PSI – 1,000 CYCLES PER MINUTE

TABLE 3–7
FLEXURAL SHEAR – 350°F CURING FILMS ON HRP CORE

ADHESIVE	LOAD AT FAILURE (LBS)	
	RT	−423°F*
HT424/HT424B	935	1,260
FM1000/BR1009-49	818	1,135
AF300/EC2254	1,030	1,191
AF300	1,118	1,305

*AT −423°F, FAILURE OCCURS WITHOUT VISUAL SEPARATION

3.2 EVALUATION OF FOAMED BUTT JOINTS

The foaming material presently used to splice the honeycomb core foam insulation for the Saturn S-IVB common bulkhead is HT-424, Type I, two component epoxy-phenolic (made by Bloomingdale Rubber Co.). Present foaming technique requires that the splice be cured separately from the two core-to-facing bonds of the sandwich structure. An investigation was initiated to evaluate other materials and foaming techniques in an effort to eliminate the separate curing process.

3.2.1 Approach

HT-424, Type II epoxy-phenolic (unsupported film) and HT-424 film (0.17 lb/ft^2, supported) were selected for testing in comparison with the Type I, two component material now in use. Splice joints were prepared with each of the three materials to determine if the splice joint could be foamed simultaneously with the cure of a core-to-facing bond.

3.2.2 Specimen Preparation

Sandwich specimens, 3 inches by 12 inches, with configurations as shown in figure 3-4 were fabricated with 2024-T4 alclad aluminum facing sheet and heat risistant phenolic (HRP) core material of 6 pound density. The bottom facing sheet of each specimen was coated with HT-424B primer, then covered with HT-424 (0.17 lb/ft^2) sheet adhesive. Two blocks of HRP foam one inch thick were placed on the adhesive sheet, leaving 1/8 inch separation between blocks for splicing.

The facing-to-core bonds of one group of specimens were then cured under pressure in an autoclave, after which the splice areas were half filled with the test foaming materials and cured separately in an oven at atmospheric pressure. The splice areas of a second group of specimens were half filled with the test foaming materials, after which the splices and the facing-to-core bonds were cured simultaneously under pressure in an autoclave. The top facing sheets were then bonded to the specimens of both groups to complete the sandwich structure.

3.2.3 Test Procedures

The sandwich specimens of both groups were tested in flexure over a six inch span with a single point load applied at a constant rate as outlined in MIL-A-25463 (ASG) and MIL-STD-401.

3.2.4 Test Results

The results of flexural tests performed on the sandwich specimens are listed in Table 3-8 and Table 3-9.

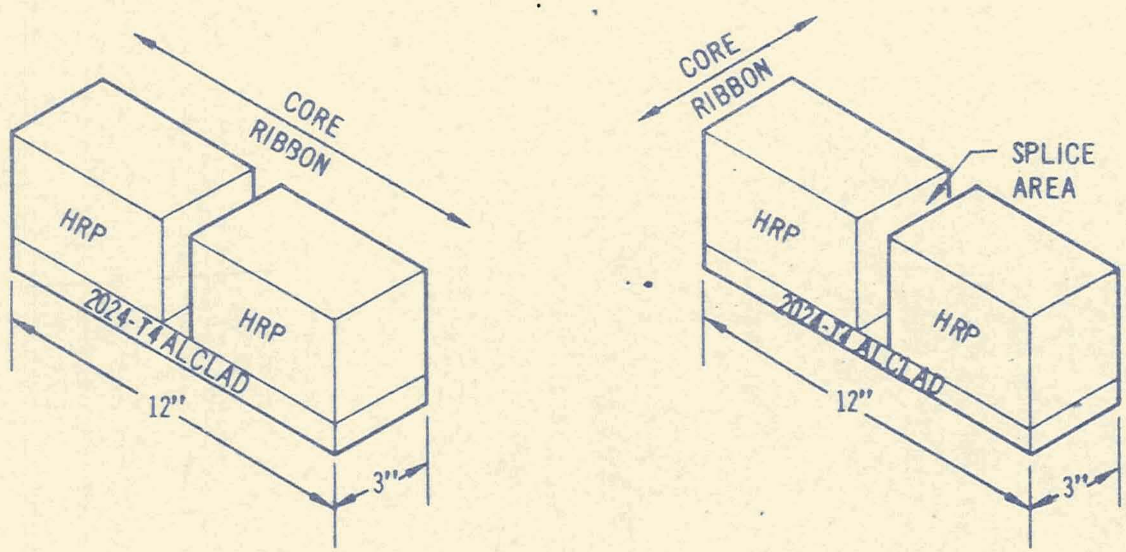
3.2.5 Conclusions

Curing the splice and the core-to-facing bond simultaneously under pressure seriously restricted the foaming action of the Type I foam as well as the supported film adhesive, producing voids at the upper surface of the joint. These voids resulted in buckling of the upper facing surface under load.

The uncured Type II film becomes tacky at room temperature and extremely brittle at temperatures below 50°F and the test results, although generally better than results obtained with the other two adhesives, are not sufficiently superior to outweigh these handling difficulties. The common bulkhead butt joints will continue to be spliced with the Type I material and cured separately.

FIGURE 3-4

CONFIGURATION OF HRP CORE SANDWICH SPECIMENS



A. SPLICE CURED UNDER PRESSURE SIMULTANEOUSLY WITH CORE-TO-FACING BOND

B. SPLICE CURED SEPARATELY AT ATMOSPHERIC PRESSURE

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TABLE 3-8
FLATWISE FLEXURE OF SEPARATELY CURED BUTT JOINTS**

SPLICE MATERIAL	LOAD AT FAILURE (LBS)	FLEXURE STRENGTH (PSI)	MODE OF FAILURE*
HT-424 FOAM TYPE I	1130	217	CB, A
	1340	215	A, S
	1330	213	A, S
	1360	218	A, DS
HT-424 FOAM TYPE II	1335	234	DS
	1510	242	CB, DS, A
	1657	266	DS
	1565	251	DS
HT-424 FILM (0.17 LB/FT^2)	1135	219	A, S
	1555	249	DS
	1695	272	DS
	1635	262	DS

*CB = COMPRESSION BUCKLING OF CORE FACING
DS = DIAGONAL CORE STRETCH AND SHEAR
A = ADHESIVE FAILURE AT FACING OR CORE
S = CORE SHEAR

**CONFIGURATION PER B. OF FIGURE 3-4

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TABLE 3–9

FLATWISE FLEXURE OF SIMULTANEOUSLY CURED BUTT JOINTS**

SPLICE MATERIAL	LOAD AT FAILURE (LBS)	FLEXURAL STRENGTH (PSI)	MODE OF FAILURE*	LOAD AT FAILURE (LBS)	FLEXURAL STRENGTH (PSI)	MODE OF FAILURE*
HT-424	1656	319	CB, JV	1685	324	CB, JV
	1885	302	CB, JV	1565	251	DB, JV
	1710	274	CB, JV	2250	361	CB, JV
	1837	295	CB, JV	2052	329	CB, JV
HT-424 FOAM, TYPE II	2075	333	CP	2240	393	DS
	2062	356	CP	2485	399	DS
	2405	430	DS	2520	402	DS
	2365	380	DS	2390	383	DS
HT-424 FILM – (0.17 LB/FT^2)	1765	339	CB, JV	1650	350	CB, JV
	2250	361	CB, JV	2140	349	CB, JV
	2150	345	DS	2255	362	CB, JV
	1965	316	CB	2255	363	CB, JV

*CB = COMPRESSION BUCKLING OF CORE FACING
JV = JOINT VOID OR PARTIALLY FILLED
CP = CORE COMPRESSED
DS = DIAGONAL CORE STRETCH AND SHEAR

** CONFIGURATION PER A. OF FIGURE 3–4

3.3 EVALUATION OF SEALANTS FOR CRYOGENIC APPLICATIONS

A sealant material suitable for use at cryogenic temperatures to provide a seal in the Saturn S-IVB fuel tank is needed. Material for this use must retain adhesion to metal and adequate flexibility at cryogenic temperatures. Polyurethane sealants and silicone sealants were investigated and comparative data obtained during the current report period.

3.3.1 Test Materials

The following two component, 100 per cent solids, polyurethane materials were tested:

a.	Narmco 7343	Narmco Industries
b.	PR-1938, semithixotropic	Products Research Co.
c.	CS-A-512, Teflon filled	Chem Seal Corp.
d.	CS-3541, semithixotropic	Chem Seal Corp.
e.	HWC-22, non-commercial	Douglas formulated
f.	HWC-1, non-commercial	Douglas formulated

The following two component, silicone sealants were tested:

a.	RTV-X-560	General Electric Co.
b.	RTV-X-511	General Electric Co.
c.	EC-2273	Minnesota Mining and Mfg. Co.

3.3.2 Specimen Preparation

3.3.2.1 Tensile Strength and Elongation

Each material was cast in 1/8 inch thick sheets and cured thirty days at room temperature.

Twenty specimens of each material were die cut as described in Federal Test Method Standard No. 601, Method 4111 after curing.

3.3.2.2 Lap Shear

Twenty specimens of each material were prepared per Federal Test Method Standard No. 175, Method 1033.1 using 7075-T6 aluminum panels overlapped one inch. The specimens were cured 30 days at room temperature. Panels for testing EC-2273, RTV-X-560, and RTV-X-511 were primed before application of the test material.

3.3.2.3 Adhesive Tensile Strength

Twelve samples of each material were applied to anodized, primed 7075-T6 aluminum sheet and cured thirty days at room temperature.

3.3.2.4 Low Temperature Flexibility

Five test specimens of each material were prepared by applying the material between two primed 7075-T6 anodized aluminum panels and curing under pressure for 16 hours at room temperature followed by 30 days at room temperature without applied pressure.

3.3.2.5 Impact Resistance

Five specimens of each material were cut from the 1/8 inch thick cured sheets prepared for the tensile strength and elongation tests.

3.3.3 Test Procedures

Low temperature flexibility was tested at -104°F and -320°F.

Impact resistance tests were performed at -320°F. All other tests were performed at each of the following temperatures:

a. 75°F

b. -104°F (after two minutes in dry ice)

c. -320°F (after soaking in liquid nitrogen)

d. -423°F (after soaking in liquid hydrogen)

3.3.3.1 Tensile Strength and Elongation

The tensile strength was determined per federal Test Method Standard No. 601, Method 4111. Elongation was determined by using the head travel of the tensile testing machine as recorded on a stress-strain graph.

3.3.3.2 Lap Shear

The lap shear strength was determined per Federal Test Method Standard No. 175, Method 1033.1.

3.3.3.3 Adhesive Tensile Strength

The adhesive tensile strength of each material was determined as outlined in Federal Test Method Standard No. 175, Method 1011.1.

3.3.3.4 Low Temperature Flexibility

The test panels were bent over a six inch radius mandrel to determine flexibility. Five specimens of each material were tested at each test temperature (-104°F and -320°F).

3.3.3.5 Impact Resistance.

The tests were performed with a Gardner impact tester on specimens submerged in liquid nitrogen to control the temperature (-320°F). Teflon specimens were tested only for comparison.

3.3.4 Test Results

The test results are listed in tables 3-10 through 3-14.

3.3.5 Conclusions

The test results indicate that the polyurethanes are slightly more satisfactory at cryogenic temperatures except for lap shear strength and flexibility. The silicone sealants apparently retain adhesion more satisfactorily at cryogenic temperatures than the polyurethanes. No further investigation is deemed necessary.

TABLE 3-10
TENSILE STRENGTH AND ELONGATION OF POLYURETHANE AND SILICONE SEALANTS*

MATERIAL	TEST TEMPERATURE (°F)							
	75		-104		-320		-423	
	TENSILE (PSI)	ELONG. (%)	TENSILE (PSI)	ELONG. (%)	TENSILE (PSI)	ELONG. (%)	TENSILE (PSI)	ELONG. (%)
NARMCO 7343	4,362	964	8,532	303	8,194	6	11,244	< 5
PR-1938	308	395	630	122	1,124 (1)	< 5	4,565	< 5
CS-A-512	1,598	960	6,688	37	3,264	< 5	10,772	< 5
CS-3541	821	500	5,738	240	4,466	6.2	19,406	< 5
HWC-22	1,060	780	4,752	186	3,730	5.5	15,697	< 5
HWC-1	3,424	1,054	6,326	372	5,768	13	16,854	< 5
RTV-X-560	646	284	1,114	360	1,207	< 5	9,496 (2)	< 5
RTV-X-511	253	224	892	438	1,382	< 5	4,503 (2)	< 5
EC-2273	1,002	303	6,142	22	2,050	< 5	6,388	< 5

*EXCEPT AS OTHERWISE NOTED, EACH VALUE IS THE AVERAGE OF 5 SPECIMENS
(1) AVERAGE OF 4 SPECIMENS (ONE SPECIMEN FRACTURED PREMATURELY)
(2) AVERAGE OF 2 SPECIMENS (TWO SPECIMENS FRACTURED PREMATURELY)

TABLE 3-11

LAP SHEAR STRENGTH OF POLYURETHANE AND SILICONE SEALANTS*

MATERIAL	TEST TEMPERATURE (°F)							
	75		-104		-320		-423	
	SHEAR (PSI)	MODE OF FAILURE**	SHEAR (PSI)	MODE OF FAILURE**	SHEAR (PSI)	MODE OF FAILURE**	SHEAR (PSI)	MODE OF FAILURE**
NARMCO 7343	558	A	1,409	A	1,670	A	1,795	A
PR-1938	299	A	1,131	A	3,228	A	2,374	A
CS-A-512	413	A	3,787	AC	2,562	60% A 40% C	2,163	85% A 15% C
CS-3541	407	A	2,738	A	1,999	A	1,876	97% A 3% C
HWC-22	387	92% A 8% C	3,202	93% A 7% C	1,252	70% A 30% C	1,337	95% A 5% C
HWC-1	534	A	978	96% A 4% C	736	A	394	A
RTV-X-560	477	40% A 60% C	1,016	C	2,906	A–P	2,003	A–P
RTV-X-511	428	C	1,038	C	2,982	A–P	1,623	A–P
EC-2273	924	C	1,488	A–P	957	A–P	911	A–P

*EACH VALUE IS THE AVERAGE OF 5 SPECIMENS
**A = 100% ADHESIVE FAILURE
C = 100% COHESIVE FAILURE
AC = 50% ADHESIVE, 50% COHESIVE FAILURE
A-P = 100% ADHESIVE FAILURE OF THE PRIMER TO THE METAL

TABLE 3–12

ADHESIVE TENSILE STRENGTH OF POLYURETHANE AND SILICONE SEALANTS*

MATERIAL	TEST TEMPERATURE (°F)							
	75		−104		−320		−423	
	ADHESIVE TENSILE (PSI)	MODE OF FAILURE**	ADHESIVE TENSILE (PSI)	MODE OF FAILURE**	ADHESIVE TENSILE (PSI)	MODE OF FAILURE**	ADHESIVE TENSILE (PSI)	MODE OF FAILURE**
NARMCO 7343	1,353	A	4,150	67% A 33% C	7,177	89% A 16% C	10,527	A
PR-1938	113	67% A 33% C	747	55% A 45% C	4,075	95% A 5% C	4,553	A
CS-A-512	305	A	3,563	10% A 90% C	7,167	C	5,733	C
CS-3541	344	A	2,835	97% A 3% C	5,733	95% A 5% C	6,520	A
HWC-22	266	AC	3,800	30% A 70% C	6,142	60% A 40% C	3,393	A
HWC-1	1,140	A	3,373	AC	6,792	A	7,587	A
RTV-X-560	291	50% C 50% A–P	687	70% C 30% A–P	5,808	10% C 90% A–P	5,473	A–P
RTV-X-511	232	A–P	580	90% C 10% A–P	4,800	10% C 90% A–P	5,200	A–P
EC-2273	912	C	3,660	A–P	5,100	A–P	5,677	A–P

*EACH VALUE IS THE AVERAGE OF 3 SPECIMENS
**A = 100% ADHESIVE FAILURE
C = 100% COHESIVE FAILURE
AC = 50% ADHESIVE, 50% COHESIVE FAILURE
A–P = ADHESIVE FAILURE OF PRIMER TO METAL

TABLE 3-13
LOW TEMPERATURE FLEXIBILITY OF POLYURETHANE AND SILICONE SEALANTS

MATERIAL	TEST TEMP (°F)	RESULTS
NARMCO 7343	−104	NO FAILURE WITH 5 SPECIMENS
	−320	NO CRACKS – MATERIAL SEPARATED FROM PANELS
PR-1938	−104	NO FAILURE WITH 5 SPECIMENS
	−320	NO FAILURE WITH 5 SPECIMENS
CS-A-512	−104	NO CRACKS – MATERIAL SEPARATED FROM ONE PANEL
	−320	NO CRACKS – ALL FIVE SPECIMENS SEPARATED FROM PANELS
CS-3541	−104	NO FAILURE WITH 5 SPECIMENS
	−320	NO CRACKS – MATERIAL SEPARATED FROM 3 PANELS
HWC-22	−104	NO FAILURE WITH 5 SPECIMENS
	−320	NO CRACKS – MATERIAL SEPARATED FROM 4 PANELS
HWC-1	−104	NO CRACKS – MATERIAL SEPARATED FROM 3 PANELS
	−320	NO CRACKS – MATERIAL SEPARATED FROM ALL 5 PANELS
RTV-X-560	−104	NO FAILURE WITH 5 SPECIMENS
	−320	NO FAILURE WITH 5 SPECIMENS
RTV-X-511	−104	NO FAILURE WITH 5 SPECIMENS
	−320	NO FAILURE WITH 5 SPECIMENS
EC-2273	−104	NO FAILURE WITH 5 SPECIMENS
	−320	SPECIMENS CRACKED AND SEPARATED FROM ALL 5 PANELS

TABLE 3–14
IMPACT RESISTANCE OF POLYURETHANE AND
SILICONE SEALANTS (–320°F)

MATERIAL	IMPACT AT* FAILURE (INCH-POUNDS)	MODE OF FAILURE
NARMCO 7343	11.6	SMALL FRACTURE, NO COMPLETE BREAK
PR-1938	3.2	BROKE INTO SEVERAL PIECES
CS-A-512	8.0	BROKE INTO SEVERAL PIECES
CS-3541	11.4	BROKE INTO SEVERAL PIECES
HWC-22	10.8	SMALL FRACTURE, NO COMPLETE BREAK
HWC-1	11.2	BROKE INTO TWO PIECES
RTV-X-560	6.0	BROKE INTO SEVERAL PIECES
RTV-X-511	5.2	BROKE INTO SEVERAL PIECES
EC-2273	3.4	SHATTERED COMPLETELY
TEFLON	12.0	BARELY VISIBLE MULTIPLE FRACTURES

*EACH VALUE IS THE AVERAGE OF 5 SPECIMENS

3.4 EFFECT OF HIGH VACUUM ON SEALANTS

Sealant materials suitable for use in the high vacuum environment of outer space are needed. A major problem encountered with sealants is outgassing under high vacuum conditions. A study has been undertaken in order to find suitable existing materials for high vacuum use.

3.4.1 Planned Approach

Selected materials are to be tested at room temperature under 10^{-5}mm of mercury. The weight loss due to outgassing, best post cure time, and maximum useful temperature will be determined. Materials giving the best results will then be subjected to an ultra-high vacuum of approximately 10^{-12} mm of mercury at various temperatures. Test results will be presented in a later issue of this report.

3.5 EVALUATION OF SILICONE SEALANTS WITH HIGH TEAR STRENGTH

An investigation was started during the last report period to determine the suitability of PR-1960 silicone sealant (Products Research Co., Burbank, California) for use in applications requiring superior tear strength (see issue one of this report). Specimens were conditioned and subjected to physical properties tests which were completed during the current report period.

3.5.1 Test Procedure

The following physical properties tests were performed on specimens of the PR-1960 silicone sealant:

a. Corrosion resistance - On QQ-A-283 aluminum panels immersed in 3 per cent sodium chloride solution for 20 days at 140°F

b. Adhesion - To primed metal as outlined in MIL-S-8802

c. Tensile strength - Tested per Federal Test Method Standard No. 601 with a jaw separation rate of 2 inches per minute

d. Hardness - Rex durometer hardness after 48 hours cure at 75°F

e. Specify gravity - Determined per MIL-S-7502

f. Tear strength - Tested per Federal Test Method Standard No. 601, using die "C"

3.5.2 Test Results

The results of physical properties tests on PR 1960 sealant are listed in Table 3-15.

3.5.3 Conclusions

PR 1960 exhibits considerably higher tear strength than the other conventionally used, room temperature curing, two part silicone sealants. The other physical properties of PR 1960 are adequate to justify its use where higher tear strength is the major consideration and all other properties are acceptable.

TABLE 3–15
PHYSICAL PROPERTIES OF PR-1960 SILICONE SEALANT

PROPERTY	RESULT
CORROSION RESISTANCE	NON CORROSIVE TO QQ-A-283 ALUMINUM
ADHESION	60 PER CENT COHESIVE FAILURE AT 8.8 POUNDS PER INCH AVERAGE PULL
TENSILE STRENGTH	401.9 PSI
ELONGATION	160 PER CENT
HARDNESS	38 (REX DUROMETER)
SPECIFIC GRAVITY	1.38
TEAR STRENGTH	52.9 POUNDS PER INCH

3.6 INVESTIGATION OF TWO COMPONENT SILICONE SEALANTS FOR USE AS ELASTOMERIC CEMENTS

During the last report period a test program was initiated to determine the suitability of a room temperature vulcanizing (RTV) silicone rubber sealant for use in the faying surface seal between the tunnel and the tunnel sealing plate of the Saturn S-IVB stage (see issue one of this report). Specimens were fabricated with and without a primer in preparation for physical properties tests. During the current report period, physical properties tests were performed on specimens of RTV-77 sealant (General Electric Co.) in conjunction with Silastic RTV 1200 primer (Dow Corning Corp.).

3.6.1 Test Procedure

The application time was determined as outlined in MIL-S-8802. The specific gravity of RTV-77 was determined as the average of five samples as outlined in Federal Test Method Standard No. 406, Method 5011. Specimens for the hardness test were prepared by applying RTV-77 sealant 1/4 inch thick between aluminum sheet 10 inches in diameter. The Shore "A" hardness was measured after curing the specimens for 16 hours at room temperature in the absence of atmospheric moisture and again after 56 hours in the presence of atmospheric moisture. The method of determining hardness with the Shore "A" durometer was per Federal Test Method Standard No. 601.

Tensile strength specimens were cured seven days at room temperature and tested as outlined in Federal Test Method Standard No. 175. The specimens were aligned in a tensile testing machine and load was applied at such a rate that rupture would occur within two to three minutes. The load at failure was recorded as the tensile strength.

3.6.2 Test Results

The specific gravity of the material was determined to be 1.37; the application time was six hours; the hardness after 16 hours cure at room temperature in the absence of atmospheric moisture was 35 (Shore "A" durometer). After 56 hours in the presence of atmospheric moisture, the Shore "A" durometer hardness was 47. The tensile strength values of the sealant at various temperatures are contained in Table 3-16.

3.6.3 Conclusion

Test results indicate that RTV-77 sealant, when used with a suitable primer, has good adhesion and is capable of curing in large sections in the absence of atmospheric moisture. It is suitable for the intended use and no further investigation is necessary.

TABLE 3–16
TENSILE STRENGTH OF PRIMED RTV-77 SEALANT

TEST TEMP (°F)	TENSILE STRENGTH		MODE OF FAILURE (PER CENT)
	AVE. OF 5 SAMPLES (PSI)	RANGE (PSI)	
400	55.8	29 TO 72	100 – COHESIVE TO PRIMER
300	134	120 TO 150	50 – COHESIVE IN RTV-77 50 – ADHESIVE TO PRIMER
150	205	170 TO 223	100 – COHESIVE IN RTV-77
77	191	140 TO 236	100 – COHESIVE IN RTV-77
–65	484	358 TO 595	60 – ADHESIVE TO RUBBER SHEET 40 – COHESIVE IN RTV-77
–100	745	700 TO 795	100 – ADHESIVE TO RUBBER SHEET

3.7 EVALUATION OF SILICONE SEALANTS NOT REQUIRING A PRIMER

During the last report period, PR-1938 silicone sealant (made by Products Research Co.) was subjected to various room temperature and elevated temperature tests (see issue one of this report). PR-1938 was found to be capable of use without a primer at temperatures ranging from 75°F to 200°F. During the current report period, the material was tested to determine its low temperature capability.

3.7.1 Test Procedure

Test specimens were cured at room temperature with 40 per cent relative humidity and tested at +75°F, -108°F, -320°F, and -423°F to determine the following properties:

a. Tensile strength and elongation	per Federal Test Method Standard No. 601, Method 4111
b. Lap shear strength	per Federal Test Method Standard No. 175, Method 1033.1
c. Adhesive tensile strength	per Federal Test Method Standard No. 175, Method 1101.1

3.7.1.1 Impact Resistance

Impact resistance specimens measuring 2 inches by 2 inches by 1/8 inch were tested while submerged in liquid nitrogen using a Gardner impact tester.

3.7.1.2 Flexibility

A uniform coating of PR-1938 sealant 50 mils thick was applied to anodized 7075-T6 aluminum test panels. After curing, the panels were tested by bending once over a 6 inch radius mandrel at -108°F and -320°F.

3.7.2 Test Results

The test results are listed in Table 3-17.

3.7.3 Conclusions

Test results indicate that PR-1938 silicone sealant is suitable for use without a primer at temperatures ranging from +200°F to -320°F. Previous experience has shown that relative humidity in excess of 40 per cent is detrimental to the material during the cure.

TABLE 3-17
LOW TEMPERATURE TEST RESULTS - PR-1938 SEALANT

TEST	TEMPERATURE	RESULTS	
TENSILE STRENGTH AND ELONGATION	+75°F	MINIMUM 298 PSI MAXIMUM 322 PSI AVERAGE 307 PSI	375% ELONGATION 400% ELONGATION 395% ELONGATION
	-104°F	MINIMUM 511 PSI MAXIMUM 856 PSI AVERAGE 630 PSI	80% ELONGATION 165% ELONGATION 122% ELONGATION
	-320°F	MINIMUM 324 PSI* MAXIMUM 2280 PSI AVERAGE 1124 PSI	1% ELONGATION 3.5% ELONGATION 2.6% ELONGATION
	-423°F	MINIMUM 1460 PSI MAXIMUM 6030 PSI AVERAGE 4565 PSI	LESS THAN 5% ELONGATION
LAP SHEAR	75°F	MINIMUM 228 PSI MAXIMUM 340 PSI AVERAGE 300 PSI	100% ADHESIVE FAILURE
	-104°F	MINIMUM 1045 PSI MAXIMUM 1205 PSI AVERAGE 1130 PSI	100% ADHESIVE FAILURE
	-320°F	MINIMUM 3100 PSI MAXIMUM 3450 PSI AVERAGE 3230 PSI	100% ADHESIVE FAILURE
	-423°F	MINIMUM 2175 PSI MAXIMUM 2490 PSI AVERAGE 2375 PSI	100% ADHESIVE FAILURE

TABLE 3–17 (CONT'D)

ADHESIVE TENSILE STRENGTH	+75° F	MINIMUM 60 PSI MAXIMUM 184 PSI AVERAGE 113 PSI	30% COHESIVE FAILURE 70% ADHESIVE FAILURE
	−104°F	MINIMUM 630 PSI MAXIMUM 890 PSI AVERAGE 747 PSI	45% COHESIVE FAILURE 55% ADHESIVE FAILURE
	−320°F	MINIMUM 3250 PSI MAXIMUM 3800 PSI AVERAGE 4075 PSI	5% COHESIVE FAILURE 95% ADJESIVE FAILURE
	−423°F	MINIMUM 2720 PSI MAXIMUM 5860 PSI AVERAGE 4553 PSI	100% ADHESIVE FAILURE
FLEXIBILITY	−104°F	NO LOSS OF ADHESION OR CRACKING	
	−320°F	NO LOSS OF ADHESION OR CRACKING	
IMPACT RESISTANCE	−320°F	ALL FIVE SPECIMENS BROKE INTO SEVERAL PIECES AT 3 INCH-POUNDS. TEFLON IN THE SAME TEST CRACKS BUT DOES NOT BREAK AT 12 INCH-POUNDS.	

*THE WIDE RANGE IN TENSILE STRENGTH VALUES IS MOST LIKELY DUE TO THE FACT THAT SOME OF THE SPECIMENS WERE NOT PERFECTLY ALIGNED IN THE JAWS BEFORE APPLYING THE LOAD. AT THIS TEMPERATURE THE SPECIMENS ARE BRITTLE.

3.8 EVALUATE HEAT SHRINKABLE TUBING FOR ELECTRICAL INSULATION AND IDENTIFICATION

Heat shrinkable tubing is used to replace stripped off insulation over soldered joints, contact pins and wire junctions. In other applications it is impression stamped and used to identify airborne, Teflon insulated wire bundles and individual wires (Teflon cannot be impression stamped). A test program was initiated to determine the suitability of the following irradiated, heat shrinkable, polyolefin tubings for these applications:

a. SRX-34 (Suprenant Mfg. Co., Clinton, Mass.)

b. Hyshrink ST-91 (Sequoia Wire Co., Redwood City, Calif.)

c. Thermofit RNF (Rayclad Tubes, Inc. Redwood City, Calif.)

3.8.1 Test Procedure

Samples of the three tubing materials were subjected to the tests and minimum requirements listed in Table 3-18.

3.8.2 Test Results

The SRX-34 material failed the markability test. All three materials were above the minimum requirements for all other tests. Results of the tests are listed in Table 3-19.

3.8.3 Conclusions

All three tubing materials are suitable for use as electrical insulation. SRX-34 tubing is not suitable for identification of wires and wire bundles since it cannot be satisfactorily marked with the Kingsley marking machine.

3.9 EVALUATION OF SOLVENT RESISTANT MARKING INK

Printed wiring boards used in the Saturn S-IVB must be marked with serial numbers for identification. Inks used for this purpose must be (1) resistant to solvents and fungi, (2) electrically nonconductive, and (3) easily applied. Tests were performed during the present report period to find an ink having these properties.

3.9.1 Specimen Preparation

Ink samples were prepared from the following materials:

a. Series M, Catalog B3 Red epoxy base ink White epoxy base ink	Warnow Process Paint Company
b. 73X black ink 73X white ink 522 black epoxy base ink	Independent Ink Company

A sample of each ink was applied with a rubber stamp to four printed wiring boards (five samples on each board). The inks were then dried as follows:

a. M-B3 epoxy inks - 90 minutes at 170°F

b. 73X inks - 16 hours (approximate) at room temperature

c. No. 522 epoxy ink - 30 minutes at 250°F

TABLE 3–18
PROCEDURES FOR TESTING HEAT SHRINKABLE TUBING

TEST	REQUIREMENTS *	TEST CONDITIONS *
DIMENSIONAL RECOVERY	FULL RECOVERY	AFTER 45 SECONDS AT 390°F
LONGITUDINAL SHRINKAGE	10% MAXIMUM	
ULTIMATE ELONGATION	200% MINIMUM	PER FED. STD. NO. 601
TENSILE STRENGTH	1500 LB/IN^2 MINIMUM	PER FEDERAL TEST METHOD STANDARD NO. 601
DIELECTRIC BREAKDOWN	500 VOLTS/MIL MINIMUM	PER ASTM D 149
LOW TEMP FLEXIBILITY	NO CRACKING	AFTER 4 HOURS AT –65°F
HEAT AGING	NO CRACKING OR SPLITTING	AFTER 96 HOURS AT 350°F
WATER ABSORPTION	.01% MAXIMUM	PER ASTM D570
VOLUME RESISTIVITY	10^{15} OHM-CM MINIMUM	PER ASTM D257
DIELECTRIC CONSTANT	2.7 MAXIMUM	PER ASTM D150
MARKABILITY	PER QQ-T-25	KINGSLEY MARKING MACHINE AT 350°F, 400°F, AND 450°F USING WHITE PIGMENT FOIL (DH-46; SWIFT & SON)
SOLVENT RESISTANCE: TENSILE STRENGTH DIELECTRIC BREAKDOWN	 1000 LB/IN^2 MINIMUM 400 VOLTS/MIL MINIMUM	AFTER 24 HOURS IMMERSION IN EACH OF FOUR DIFFERENT SOLVENTS
SPECIFIC GRAVITY	1.30 MAXIMUM	PER ZZ-R-601

*EXCEPT AS OTHERWISE NOTED, REQUIREMENTS AND CONDITIONS ARE PER IP 20023.

TABLE 3–19
HEAT SHRINKABLE TUBING TEST RESULTS

TEST	TEST RESULTS		
	THERMOFIT RNF	HYSHRINK ST-91	SRX-34
DIMENSIONAL RECOVERY	PASSED	PASSED	PASSED
LONGITUDINAL SHRINKAGE	5%	5%	7.5%
ULTIMATE ELONGATION	200% +	200% +	200% +
TENSILE STRENGTH	4465 LB/IN^2	4120 LB/IN^2	4500 LB/IN^2
DIELECTRIC BREAKDOWN	2000 VOLTS/MIL	2000 VOLTS/MIL	1480 VOLTS/MIL
LOW TEMP FLEXIBILITY	PASSED	PASSED	PASSED
HEAT AGING	PASSED	PASSED	PASSED
WATER ABSORPTION	LESS THAN .01%	LESS THAN .01%	LESS THAN .01%
VOLUME RESISTIVITY	6×10^{15} OHM-CM	6×10^{15} OHM-CM	5×10^{15} OHM-CM
DIELECTRIC CONSTANT	2.25	2.32	2.40
MARKABILITY	PASSED	PASSED	FAILED
SOLVENT RESISTANCE:* TENSILE STRENGTH DIELECTRIC BREAKDOWN	 4014 LB/IN^2 1493 VOLTS/MIL	 3806 LB/IN^2 1666 B 1666 VOLTS/MIL	 3596 LB/IN^2 1313 VOLTS/MIL
SPECIFIC GRAVITY	PASSED	PASSED	PASSED

*EACH VALUE IS THE AVERAGE OF FOUR SPECIMENS

3.9.2 Test Procedure

Each of the four printed wiring boards (containing all five inks) was subjected to a different solvent. The test solvents were as follows:

a. Sovasol No. 5

b. Freon TF — E. I. du Pont de Nemours and Company

c. Freon TMC

d. Freon PC

The boards were washed in the solvents for two minutes, removed, and scrubbed for one minute with a non-metallic bristle brush. All inks which passed this test were subjected to the following fungi:

a. Chaetomium

b. Globosum

c. Penicillium citrinum

d. Aspergillius niger

e. Aspergillius flavis

Those inks which passed the fungus tests were tested for electrical resistivity using a bullseye pattern with .050 inch space between the outer ring and the circular center pattern. Each printed wiring board was conditioned for 80 hours in a controlled temperature-humidity chamber prior to resistance testing.

3.9.3 Test Results

The results of solvent resistance testing are listed in Table 3-20. Epoxy base inks were not appreciably affected by solvents or fungi. All epoxy base inks, except the No. 522 black ink were determined to be non-conductive.

3.9.4 Conclusions

Results indicate that the epoxy base inks, except for No. 522 black ink, are better suited for marking printed wiring boards than the other inks tested. Epoxy base inks are now being used for this purpose in the Saturn S-IVB program.

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TABLE 3-20
SOLVENT RESISTANCE OF PRINTED WIRING BOARD INKS

INK SAMPLE	REACTION TO SOLVENTS*			
	SOVASOL NO. 5	FREON TF	FREON TMC	FREON PC
WARNOW RED (EPOXY)	NC	NC	NC	NC
WARNOW WHITE (EPOXY)	NC	NC	NC	NC
NO. 522 BLACK (EPOXY)	VERY SLIGHT FADING	NC	VERY SLIGHT FADING	NC
NO. 73X BLACK	NC	NC	VERY SLIGHT FADING	VERY SLIGHT FADING
NO. 73X WHITE	VERY SLIGHT FADING	NC	COMPLETELY BLURRED	HEAVILY INKED AREAS COMPLETELY BLURRED. LIGHTLY INKED AREAS NOTICEABLY FADED

*NC = NO NOTICEABLE CHANGE

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3.10 EVALUATION OF SOLDERLESS WIRE WRAP CONNECTIONS

A test program was initiated to determine the ability of solderless wire wrap connections to withstand the environmental stresses anticipated for Saturn S-IVB ground equipment and to determine any significant differences in the quality of three wire wraps on the same terminal.

3.10.1 Test Procedures

Twenty-six printed wiring board wire wrap connectors, each containing 64 wire wrap terminals, and 44 unmounted wire wrap terminals were tested. Approximately half of the connections were wrapped with an air operated wrapping tool; the other half with a battery operated tool. Both 22 gage and 24 gage wire were used. The wrapped connections were subjected to the following tests:

a. Unwrap resistance

b. Gas tightness

c. Stripping force

d. Thermal shock

e. Current overload

f. Salt spray resistance

g. Vibration

h. Shock

The above tests were performed to determine conformance of the connections with the requirements outlined in 1P00032.

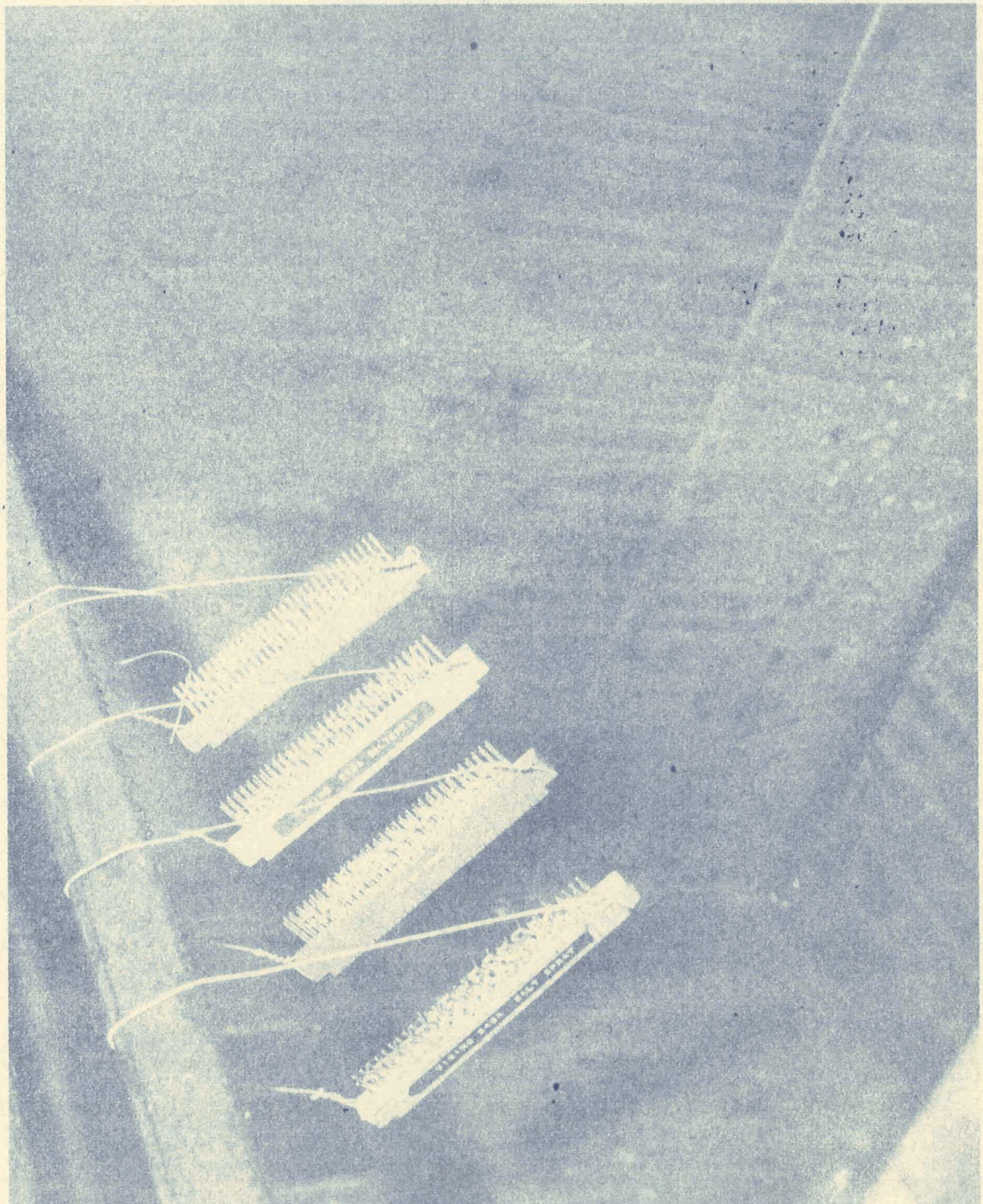
The millivolt drop was measured after each test. Each unmounted terminal was wrapped at three wire levels with uniform spacing between levels. The terminals were square in cross section and measured .045 inch by .045 inch.

3.10.2 Test Results

The results of all tests were satisfactory. A slight increase in the mean value of millivolt drop was noted after all environmental testing. The value, however, was below the allowable maximum of two millivolts. No defective connections resulted with either the air operated or battery operated wrapping tool. The results of salt spray testing were satisfactory. Figure 3-5 shows the connectors mounted in the salt spray tank. A 20 per cent solution was used. The results of stripping force tests were comparable for all three wire wrap levels.

3.10.3 Conclusions

Solderless wire wrap connections are apparently satisfactory for use in ground support equipment. There is no significant difference in quality for the three wire wrap levels.



SOLDERLESS WIRE WRAP CONNECTORS MOUNTED IN SALT SPRAY TANK

FIGURE 3-5

3.11 EVALUATION OF A CRYOGENIC SERVICEABLE POLYMER

During the last report period, preliminary tests were made to determine the elastomeric properties of ET-9 epoxy polymer (made by Narmco). These tests, conducted at -320°F, indicated that the material possesses practically no flexibility when cured using the recommended curing agent (4,4" methylene dianiline). Investigation continued during the current report period to find a more efficient cross linking agent which would lower the second order transition point and thereby improve low temperature flexibility.

3.11.1 Additional Testing

The following possible cross linking agents were checked in the ET-9 polymer:

a. Methylene-bis-orthochloroaniline (MOCA)

b. M-phenylene diamine

c. M-toluene diamine

d. Triethylene tetramine

e. Aldehyde-amine (trimene base)

f. Methylene-bis-maleimide

g. 4-Methoxy phenylmaleimide

h. N-phenylmaleimide

i. Maleic anhydride

3.11.2 Test Results

None of the amines, imides, or anhydrides equalled the cross linking efficiency of 4,4" methylene dianiline.

3.11.3 Conclusions

Test results indicate that the usefulness of ET-9 is doubtful in cryogenic sealing applications. The relative high second order transition temperature (254°K to 264°K) of the polymer, compared to other elastomeric materials, makes it a secondary choice for further investigation.

3.12 DEVELOPMENT OF AN ELASTOMERIC VIBRATION DAMPENER

A material suitable for use as a vibration dampener to isolate the cylindrical oxidizer tank of the attitude control system from destructive vibration is being developed. The material must have low compression set, low heat build-up, a K value of less than 0.10 BTU/hr./ft./°F, and a deflection of approximately 17 per cent under a load of 54 psi. All of the above property values must be retained in a high vacuum.

Several compounds, using butyl, neoprene, silicone, and natural rubber as base polymers, were formulated during the last report period.

3.12.1 Preliminary Evaluation

Test results to date indicate that the butyl compound has the best vibration dampening properties. Several adhesives are being tested to find the most suitable material for bonding cured butyl rubber to the stainless steel oxidizer tank. EC-2216 apoxy adhesive (Minnesota Mining and Mfg.) was tested and found to have very low bond strength between butyl and stainless steel. A solvent base adhesive, such as EC-1099, produces good bond strength but complete removal of volatiles is necessary for high vacuum use.

3.12.2 Future Investigation

Other butyl compounds will be prepared with lower hardness (at some sacrifice of compression set properties) and compared with the preliminary butyl compound.

Comparison studies are also being made between a butyl compound in the 65 to 70 Shore durometer hardness range and the softer butyl stocks. Various adhesives will be tested under actual high vacuum conditions to obtain the optimum bond strength between butyl rubber and stainless steel.

3.13 INVESTIGATION OF O-RING, SEAL, AND GASKET MATERIALS COMPATIBLE WITH N_2O_4 AND MIXED HYDRAZINE

Several materials have been tested to determine compatibility with liquid propellants such as nitrogen tetroxide (N_2O_4), and mixed hydrazine (see issue one of this report). Only one commercially available elastomeric material is considered reasonably suitable for limited exposure in the liquids at present. The material is SR-634-70 butyl (Stillman Rubber Co.). Elastomeric materials capable of existing in liquid propellants are needed for O-rings, seals, gaskets, and the fabrication of an expulsion bladder.

3.13.1 <u>Additional Investigation</u>

3.13.1.1 <u>Exposure in N_2O_4</u>

The following materials were tested in N_2O_4 and discarded because of excessive deterioration:

a. SMR-81 butyl compound (Stoner Rubber Co.)

b. M-863 EPR compound (Connecticutt Hard Rubber)

c. 846-80R butyl compound (Plastics and Rubber Products Co.)

d. B-496-7 butyl compound (Parker Seal Co.)

A butyl series and an EPR series, both compounded by Douglas Aircraft Company, were tested and discarded because of excessive loss of properties and swelling. The Hydropol base compounds prepared by Douglas Aircraft Company (see issue one of this report) show reasonably good retention of properties but efforts to soften the material have been unsuccessful.

A polybutadiene series and a neoprene base compound, both prepared by Douglas Aircraft Company, exhibited severe loss of properties within 24 hours exposure to the liquid propellants.

Plastic films which have been exposed are as follows:

a. Aclar (polycarbonate) — Allied Chemical Co.

good retention of properties

b. FEP Teflon — du Pont Chemical Co.

good retention of properties

c. Mylar (polyester) — du Pont Chemical Co.

deteriorated completely in less than 24 hours

3.13.1.2 Exposure in Mixed Hydrazine

Mixed hydrazine is much less severe than N_2O_4. Almost all of the materials tested retained 75 per cent or more of their original properties after one week exposure at room temperature. Materials exposed to N_2O_4, and determined to be reasonably resistant, will be checked in mixed hydrazine.

3.13.2 Conclusion

Materials such as Teflon are not particularly suited for use in expulsion bladder fabrication as compared with elastomeric materials. Investigation will continue in order to develop additional materials for use in N_2O_4 and mixed hydrazine.

3.14 EVALUATION OF HYDRAULIC PACKING AND SEAL MATERIALS FOR HIGH VACUUM ENVIRONMENT

The Saturn S-IVB actuator seals are made of Buna-N rubber with Teflon back-up rings. The seal material is considered adequate for earth orbit missions. Plasticizers and oils in the Buna-N compound (as well as a limited temperature range) make the material marginal for use in the high vacuum - low temperature environment of outer space because of pinch-loss from outgassing and flexibility-loss at low temperature. A test program was initiated to find materials which would provide minimum leakage and improved reliability under high vacuum-low temperature conditions.

3.14.1 Test Materials

3.14.1.1 O-rings

Sets of O-rings fabricated from the following materials were selected for testing:

a.	SR 832-75 Buna-N (used as control)	Stillman Rubber Co.
b.	SR 269-75 polyurethane	
c.	1000 - 70 silicone	Hadbar, Inc.
d.	1000 - 80 silicone	
e.	Viton low temperature rubber	du Pont Chemical Co.

3.14.1.2 Back-up Rings

Teflon back-up rings of the (1) multi-coil type, (2) single ring type, and (3) slipper type were selected for testing in conjunction with the O-rings listed above.

3.14.2 Future Testing

The dimensions of the O-rings will be recorded and tests will be conducted in a suitable testing apparatus. Results will be presented in a later issue of this report.

3.15 LOX COMPATIBLE MATERIALS

Materials which tend to detonate upon impact when in contact with liquid oxygen (LOX) cannot be used in the Saturn S-IVB LOX system. Continual testing must be done in order to find LOX compatible materials suitable for design required applications (see issue one of this report).

3.15.1 Test Procedure

Each material is subjected to a series of impacts under LOX using an impact testing machine. The number of impacts and force of impact vary within specified limits with each type of material tested.

3.15.2 Test Results

A list of materials recently found to be compatible in LOX is contained in Table 3-21. Additional materials, tested during the last report period, are contained in issue one of this report. Recently tested materials determined to be incompatible with LOX are as follows:

a.	LS-9816 Fluorobestos	Raybestos Co.
b.	Epoxy-alumina mixture	Richie
c.	XW-012-80	Products Research
	XW-014-80	
d.	Narmco 7343 Adhesive	Narmco Industries

In addition to the above materials, SKL-4 spotcheck penetrant solution (Magnaflux Corporation) was determined incompatible in concentrated form. It is currently used, however, in a 3 to 1 solution with water for detecting cracks. The dilute solution has been tested and, as previously reported, is considered impact compatible with LOX.

3.15.3 Conclusion

Testing to determine LOX compatible materials will continue in the future as dictated by new, design required materials.

TABLE 3-21
LOX COMPATIBLE MATERIALS

MATERIAL	SOURCE
XW-013-80	PRODUCTS RESEARCH CO.
SHERLOCK GAS AND AIR LEAK DETECTOR	ZEP-AERO CO.
905 LOX SEAL CHECK FLUID	SEMCO CO.
SLIPSPRAY	DuPONT CHEMICAL
TAT'L LEAK DETECTOR	J AND S SALES AND SERVICE
DYNA THERM D4327 COATING	DYNA-THERM CO.
DRILUBE 822B	DRILUBE CO.

SECTION IV

DEVELOPMENT OF PROCESSES

Recent progress made in the development of new production processes and the improvement of existing processes related to the Saturn S-IVB is summarized in this section.

4.1 VACUUMATIC BRAZING PROCESS FOR SATURN COLD PLATES

Electronic components located in the forward inter-stage of the Saturn S-IVB are to be cooled by the circulation of a liquid through the mounting plates (cold plates). Fabrication of these cold plates will be accomplished by a bonding process using a nitrile - phenolic bonding agent. Tests conducted on bonded cold plates have shown the method to be satisfactory. Flatness of the plates can be held to within .003 inch over a coolant area of 22 inches by 41 inches. The results of pressure drop tests, proof tests, and burst tests exceed design criteria. Since these plates are to be made from heat treatable aluminum alloy, the Douglas vacuumatic process was proposed as an alternate method of joining the detail parts of the plates. The vacuumatic process does not require the use of cleaning fluxes and the internal design of the plate is such that chemical milling and brazing techniques could easily be used in production. A test program was initiated to establish production feasibility.

4.1.1 Test Procedure

Four small, sample cold plates were produced by the vacuumatic process using number 23 brazing sheet (made by Alcoa). Due to the results obtained with the first three sample cold plates, modifications of the process and the brazing fixture were incorporated before producing and heat treating the fourth sample. This fourth sample was then tested to determine the liquid pressure drop from the inlet to outlet.

The brazing sheet (number 23, Type 6951 alloy) was tested to determine yield strength, ultimate strength, and elongation after heat treatment.

4.1.2 Test Results

The pressure drop test results were satisfactory. Strength levels of the brazing sheet are listed in Table 4-1. Warpage of the part occurred during the solution (heat treat) process.

4.1.3 Conclusion

The Douglas vacuumatic brazing process is feasible for production brazing of the Saturn S-IVB cold plates. The brazing sheet strength levels after heat treatment meet design requirements. Warpage, however, which occurs during heat treatment of the part must be eliminated or substantialy reduced. Future work will be done to refine the solution and aging (heat treat) processes in an effort to eliminate warpage.

TABLE 4–1
STRENGTH LEVELS OF HEAT TREATED 6951 BRAZING SHEET*

NUMBER OF SAMPLES	SHEET GAGE (INCH)	YIELD** STRENGTH (PSI)	ULTIMATE STRENGTH (PSI)	ELONGATION (PER CENT)
12	.020	HIGH 37,925 LOW 32,335	41,605 41,495	9 8
6	.040	HIGH 32,085 LOW 31,295	37,865 37,710	10 10
15	.060	HIGH 37,510 LOW 36,120	43,220 41,990	12 12

*MINIMUM DESIGN REQUIRED VALUES ARE 30,000 PSI YIELD, 35,000 PSI ULTIMATE, AND 8 PER CENT ELONGATION IN 2 INCHES.

**HIGH AND LOW VALUES ARE BASED ON YIELD.

4.2 FRACTURE TOUGHNESS OF 2014-T6 WELDMENTS

Mechanical properties testing of welds prepared with 4043 and 716 filler wire were conducted during the last report period to obtain data covering the process of welding critical structures intended for use at cryogenic temperatures. Tensile specimens containing shallow cracks up to .100 inch in depth were prepared for testing at room temperature and -423°F (see issue one of this report).

4.2.1 Additional Progress

Tensile testing of the welds is now complete. Fractographic and microscopic studies of the weld structure are currently in progress. Upon completion of these studies, the results will be correlated and presented in this report.

4.3 IMPROVEMENT OF DUCTILITY IN SATURN S-IVB WELDS

Thermal cycles used in bonding the honeycomb to the common bulkhead domes introduce an aging effect upon welds which increases tensile properties but, at the same time, lowers ductility. As a result, common bulkhead meridian welds, after one or more cure cycles, possess marginal ductility. An investigation is being conducted to determine a method of improving the ductility of these welds.

4.3.1 Approach

Test programs were initiated in order to (1) determine the effect of controlled overaging on ductility and (2) determine the feasibility of improving ductility by reducing the iron content in the weld deposit.

4.3.2 Test Procedures

4.3.2.1 Overaging

Welds were made in 2014-T6 aluminum using 4043 filler wire and then overaged by heating with a welding torch. Temperatures were controlled by varying the rate of travel of the torch. The overaging temperatures ranged from 550°F to 700°F. After overaging, the welds were subjected to four simulated bonding cycles and tested for ductility at -320°F. Control specimens, which were not overaged, were also tested in the same manner.

4.3.2.2 Iron Content Reduction

Three ingots were cast, extruded, and drawn into 3/64 inch diameter welding electrode with chemical compositions per Table 4-2. These compositions represent (1) 4043 aluminum with low iron, (2) a typical 2014-T6 aluminum weld deposit with low iron content, and (3) a typical 2014-T6 aluminum weld deposit with normal iron content. Butt welds, of the Saturn production type, were prepared using both standard 4043 aluminum electrode and the low iron content electrode drawn from ingot number 1. Ductility tests were conducted with specimens from both welds at -321°F. Bead-on plate welds were made with wire from ingots 2 and 3 to compare all weld metal tensile specimens of low and normal iron content.

4.3.3 Test Results

4.3.3.1 Overaging

The ductility of overaged specimens was markedly decreased in all cases. Examination of the weld microstructure revealed a similar structure in all overaged specimens.

4.3.3.2 Iron Content Reduction

No improvement in ductility occurred with the low iron content 4043 filler metal. Spectrographic analysis showed the iron content in the weld deposit to be 0.28 per cent.

Testing of ingots 2 and 3 is not complete to date. Tensile specimens of each type will be tested at room temperature and -423°F in both the as-welded condition and after curing.

4.3.4 Conclusions

4.3.4.1 Overaging

Test results indicate that the development of an effective overaging process would require extensive study of the metallurgical behavior of the weld. An adequate procedure is not deemed practicable at present.

4.3.4.2 Iron Content Reduction

The results obtained with the 4043 filler wire are considered inconclusive since, due to dilution with the parent material which was found to contain 0.55 per cent iron, the iron content was excessive. The results of tensile testing of ingots 2 and 3 will be presented in a later issue of this report.

TABLE 4–2
COMPOSITION OF LOW IRON CONTENT, DUCTILITY TEST INGOTS

ELEMENT	PER CENT COMPOSITION		
	INGOT NUMBER		
	1	2	3
COPPER	-----	3.0	3.0
SILICON	5.0	2.5	2.5
MAGNESIUM	-----	0.4	0.4
MANGANESE	-----	0.5	0.5
IRON	< 0.10	< 0.10	0.5
ALUMINUM	REMAINDER	REMAINDER	REMAINDER

4.4 AUTOMATIC D.C. TIG WELDING SATURN FITTINGS

The semi-automatic metal-inert gas (MIG) welding process is presently used in production for making fitting to dome welds. The automatic, direct current, tungsten-inert gas (D.C. TIG) welding process would offer the following advantages:

a. Full automatic operation

b. Minimized weld defects and repairs

c. Minimum distortion and shrinkage

d. Consistently uniform weld deposits

e. Reduced weld time

A study was conducted to determine the feasibility of using the D.C. TIG process for production welding of fitting to dome welds.

4.4.1 Test Program

Laboratory tests were conducted using the Linde Missile Maker (see issue one of this report) with temporary production tooling. Nine weld specimens were prepared by inserting 6061-T6 aluminum fittings into openings in 2014-T6 aluminum dome sections. Seven of the welds were made using the double fillet technique; the other two were completed in a single pass. Joint openings at the root of the weld (tolerance between mating members) were varied from a tight fit to a 1/16 inch clearance. Procedures and weld parameters used in preparation of the specimens are listed in Table 4-3. Eight of the nine specimens were shear tested. All specimens were subjected to dye penetrant, radiographic, and visual inspections.

4.4.2 Test Results

The results of inspections and shear testing are listed in Table 4-4. The results of these tests and additional laboratory study proved the feasibility of welding fittings into the dome section by the D.C. TIG process. Minute porosity, approaching Class I level, was encountered on joints having variations in fit-up exceeding .030 inch.

4.4.3 Additional Investigation

Shop tests, based on results obtained in the laboratory, were conducted with the Linde Missile Maker set-up for welding on production tooling. The double fillet weld technique was used to weld 1 inch, 4 inch, 5 1/2 inch, and 10 inch diameter fittings in 0.113 inch and 0.190 inch domes.

Weld parameters and machine settings suitable for production were developed from the shop tests. Figure 4-1 contains the typical D.C. TIG weld parameter sequence for welding 4 inch O.D. fittings to the 0.190 inch aft dome.

4.4.4 Conclusions

The automatic D.C. TIG process, used in conjunction with the Linde Missile Maker, is an excellent combination of process and equipment. The process has been certified and is currently used in Saturn S-IVB production fabrication.

TABLE 4-3
PROCEDURES AND WELD PARAMETERS FOR LABORATORY D.C. TIG WELD TESTS*

WELD NO.	CURRENT (AMP. D.C. S.P.)	ARC VOLTAGE (VOLTS)	WELD** SPEED (IPM)	WIRE SPEED (IPM)	NUMBER PASSES	ROOT OPENING
1	130	14.5	15	65	2	TIGHT
2	130	12.5	15	65	2	TIGHT
3	130	12.0	15	65	2	TIGHT
4	130	11.0	15	65	2	TIGHT
5	130	12.0	15	65	2	TIGHT
6	128	11.5	15	65	1	TIGHT
7	130	12.0	15	65	2	.030 INCH
8	130	12.0	15	65	1	.045 INCH
9	130	12.0	15	65	2	.060 INCH

*LIST OF WELDING EQUIPMENT USED:

POWER SOURCE AND CONTROL –	LINDE MISSILE MAKER
TORCH –	LINDE HW-20 (STRAIGHT)
ELECTRODE –	3/32 INCH DIAMETER TUNGSTEN, 2 PER CENT THORIA
SHIELDING GAS CUP –	NO. 5 CERAMIC (5/16 INCH I.D.)
SHIELDING GAS AND FLOW –	HELIUM AT 65 C.F.H.
WELD POSITION AND JOINT –	HORIZONTAL FILLET
FILLER WIRE –	1/16 INCH DIAMETER, 4043 ALUMINUM

**TORCH STATIONARY, PART MOVING

TABLE 4–4
LABORATORY FITTING TO DOME WELD RESULTS*

WELD NUMBER	NUMBER OF PASSES	ULTIMATE SHEAR (PSI)	JOINT ROOT OPENING	INSPECTION RESULTS		
				VISUAL DEFECTS	RADIOGRAPHIC	PENETRANT
1	2	35,100	TIGHT	NONE	CLEAR	NO INDICATIONS
2	2	42,200	TIGHT	NONE	CLEAR	NO INDICATIONS
3	2	38,800	TIGHT	NONE	CLEAR	NO INDICATIONS
4	2	45,100	TIGHT	NONE	CLEAR	NO INDICATIONS
5	2	42,600	TIGHT	NONE	CLEAR	NO INDICATIONS
6	1	25,800	TIGHT	NONE	CLEAR	NO INDICATIONS
7	2	43,500	.030 INCH	NONE	CLEAR	NO INDICATIONS
8	1	23,400	.045 INCH	EXCESSIVE PENETRATION IN ROOT OPENING AREA	SCATTERED ROOT POROSITY	NO INDICATIONS
9	2	NOT TESTED	.060 INCH	EXCESSIVE PENETRATION IN ROOT OPENING AREA	SCATTERED ROOT POROSITY	NO INDICATIONS

*FITTING: 3 INCH O.D., 1/8 INCH WALL, 6061-T6 ALUMINUM
DOME: 2014-T6 ALUMINUM, 1/8 INCH THICK

D.C. TIG WELD PARAMETER SEQUENCE

4 INCH O.D. FITTING TO 0.190 INCH AFT DOME

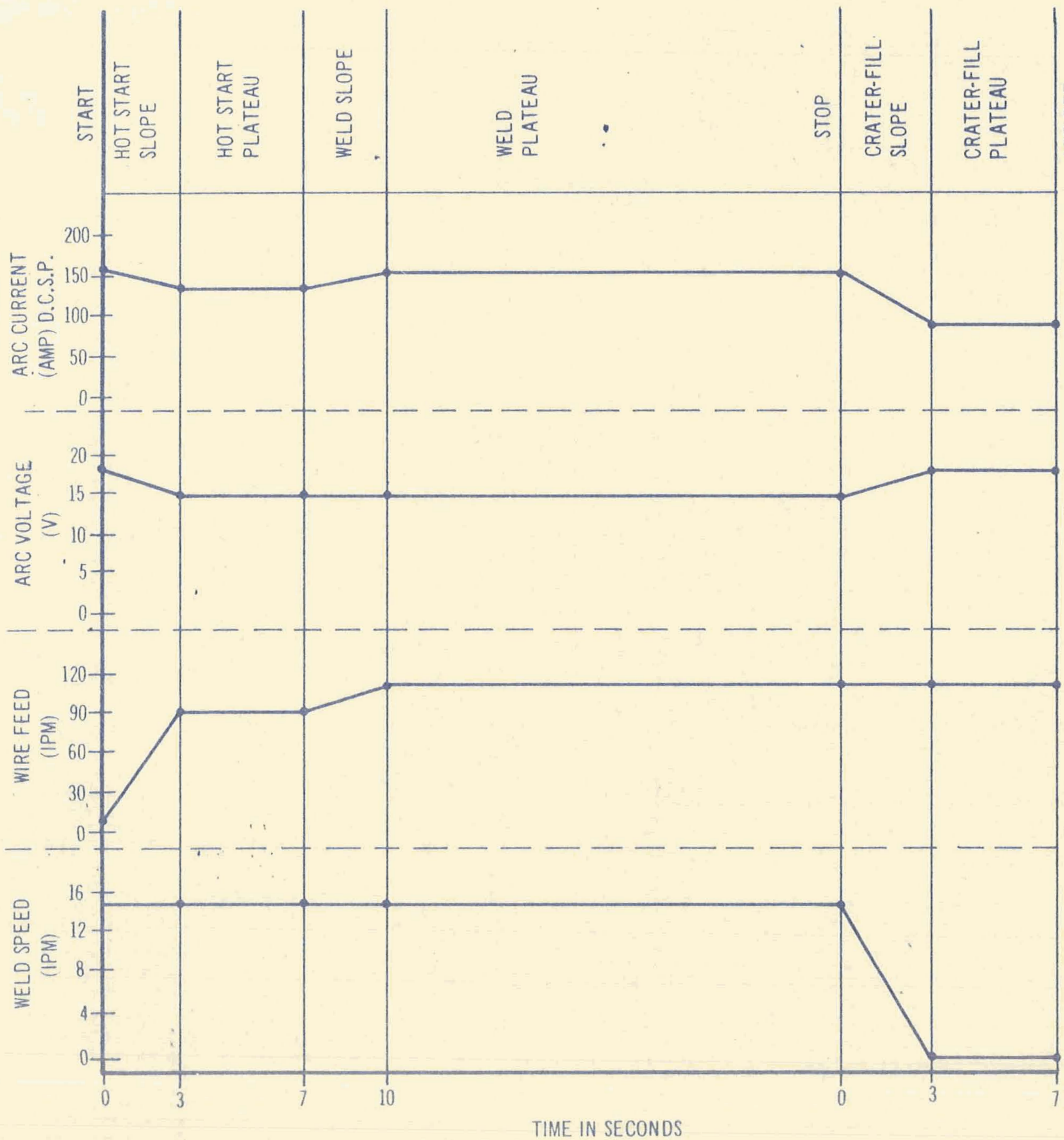


FIGURE 4-1

4.5 AUTOMATIC D.C. TIG WELDING ALUMINUM BUTT JOINTS

Preliminary data obtained from MIG and TIG production process evaluation (see issue one of this report) indicated several areas of Saturn fabrication suitable for adaption of the D.C. TIG process. A complete investigation, designed to apply the automatic D.C. TIG process to production welding of aluminum butt-joints, is currently in progress.

4.5.1 Approach

Test welds are being prepared in 2014-T6 and 6061-T6 aluminum alloys from 0.030 inch to 0.375 inch thick. The current studies are being made to obtain the optimum design for the following parameters:

a. Back-up bar material

b. Groove configuration

c. Torch angle

d. Electrode diameter

e. Welding tip geometry

Weld tests are being conducted to determine (1) machine settings for all weld joints, (2) joint fit-up (tolerance), and (3) production welding tooling requirements. A study is also scheduled to determine the effects of repair welding on mechanical properties. All mechanical property data will be obtained from tensile strength tests conducted at room temperature on both transverse and longitudinal specimens. Results of these studies will be presented in a later issue of this report.

4.6 INVESTIGATION OF GAS MIXTURES FOR AUTOMATIC MIG WELDING

Weld studies, performed earlier as part of a Douglas Aircraft Company funded research program, indicated that the quality of automatic MIG (metal-inert gas) welds in 2014-T6 aluminum could be improved through the use of shielding gases of special composition. Tests are being conducted to determine the feasibility of improving the quality of Saturn S-IVB production welds with shielding gases of special composition.

4.6.1 Test Program

Using various shielding gas compositions, four single-pass and four multi-pass automatic MIG butt welds were prepared in 2014-T6 aluminum plate 3/8 inch thick. Table 4-5 contains a list of the gas mixtures used. All welds were evaluated by visual, radiographic, and dye penetrant inspections. Mechanical tests will be made at a later date.

4.6.2 Test Results

Inspection results are summarized in Table 4-5.

4.6.3 Future Work

Single and multi-pass lap welds are being prepared using the same material and gas mixtures as above. Results of inspection, as well as mechanical tests on both the butt and lap welds, will be presented in a later issue of this report.

TABLE 4–5
EFFECTS OF VARIOUS SHIELDING GAS COMPOSITIONS
ON MIG BUTT WELDS

SHIELDING GAS COMPOSITION	NUMBER WELD PASSES	INSPECTION RESULTS		
		RADIOGRAPHIC	DYE PENETRANT	VISUAL
ARGON 99.9% OXYGEN 0.1%	1	CLEAR, CLASS I	NO INDICATIONS	NO APPARENT DEFECTS
	6	SCATTERED FINE POROSITY CLASS II	FINE SURFACE POROSITY	
HELIUM 75 % ARGON 25 % OXYGEN 0.1%	1	CLEAR, CLASS I	SLIGHT SURFACE POROSITY	NO APPARENT DEFECTS (WIDE CROWN)
	5	CLEAR, CLASS I	FINE SURFACE POROSITY	NO APPARENT DEFECTS
HELIUM 75 % ARGON 25 %	1	SCATTERED POROSITY CLASS II TO III	SURFACE POROSITY	NO APPARENT DEFECTS (VERY WIDE CROWN, IRREGULAR UNDERBEAD)
	5	SCATTERED FINE POROSITY CLASS II	FINE SURFACE POROSITY	NO APPARENT DEFECTS
ARGON	1	CLEAR, CLASS I	NO INDICATIONS	NO APPARENT DEFECTS
	6	SCATTERED FINE POROSITY CLASS II	FINE SURFACE POROSITY	

4.7 ELECTRON BEAM WELDING COMMON BULKHEAD "T" EXTRUSIONS

A test program was conducted during the current report period to determine the feasibility of joining the "T" extrusion segments in the common bulkhead by using the electron beam process. In addition to increased weld quality, the electron beam process offers the following advantages over the manual MIG process now used in production:

a. Full automatic operation

b. A minimum of weld defects and repairs

c. A minimum of distortion and shrinkage

d. More efficient joints and joint preparation

e. Reduced weld time

4.7.1 Test Procedure

Machined "T" bars with cross sections similar to production extrusions, were prepared from 2014-T6 wrought aluminum plate. Electron beam welds were first made on plate to develop machine settings for the various thicknesses encountered in the "T" joint. These settings were then used to prepare butt welds in the machined "T" bars. Two weld passes were made in each joint to weld (1) the leg of the "T", and (2) the base of the "T". Weld starts and stops were made on end tabs. Two "T" butt joint samples were welded, using the optimum settings developed, and inspected by visual and dye penetrant methods. Tensile tests were made on specimens machined from various locations within the samples (see figure 4-2).

Welds were made on plate and in butt joints in 2 1/4 inch thick, 2014-T6 aluminum to determine the feasibility of making the "T" extrusion weld in a single pass. Consistent penetration could not be achieved, however, with the available electron beam welding equipment; therefore, mechanical tests were not performed on the specimens.

4.7.2 Test Results

Dye penetrant inspection of the two-pass "T" butt welds gave no indications. Visual inspection gave the following results for both samples:

a. Slight undercut along surfaces of both passes

b. Positive underbead reinforcement, both passes

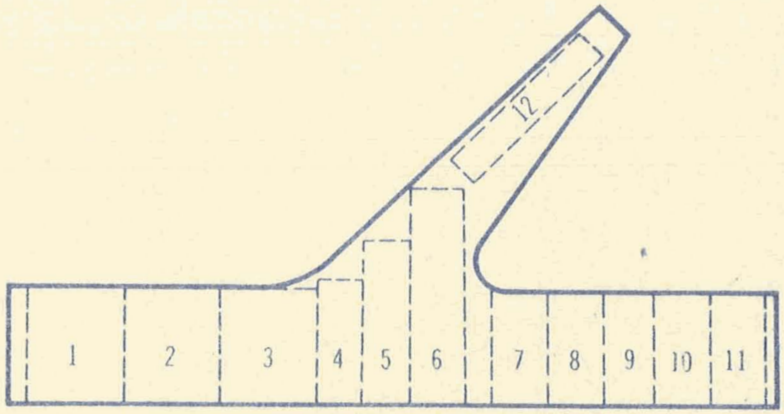
c. Small void in underbead at junction of leg and base

d. Several small voids on top surface of leg where penetration of beam is lost in second pass.

Tensile test results are listed in Table 4-6. The lowest tensile values occurred in the root area of the "T".

4.7.3 Conclusions

The study indicates that electron beam welding the common bulkhead "T" extrusions is feasible. Loss of tensile strength in the root area of the "T" was due to regularly occurring, small, longitudinal voids where the two weld passes tied together. Such voids are apparently characteristic where full penetration of the beam through the workpiece is not achieved. Weld soundness can be obtained with the electron beam process provided a single pass process can be developed. The present equipment is inadequate for single-pass welding aluminum of the required thickness. Additional work, utilizing more powerful equipment, will be done to develop production capability of electron beam welding for the Saturn S-IVB.



TENSILE TEST SPECIMEN DERIVATION
FIGURE 4-2

TABLE 4-6
TENSILE PROPERTIES OF ELECTRON BEAM BUTT WELDS

SPECIMEN	FTU (PSI)	ELONGATION IN 2 INCHES (%)
1	54,400	1.0
2	50,700	1.5
3	47,600	1.5
4	42,200	1.5
5	30,700	0.5
6	36,700	1.0
7	48,300	1.0
8	50,300	1.0
9	50,200	1.0
10	45,800	1.0
11	59,100	1.0
12	35,400	1.0

4.8 ELECTRON BEAM WELDING TBF ROUND FLANGE RECEPTACLES

Installation of the through-bulkhead feed through (TBF) round flange, hermetic receptacle requires a welded joint to insure absolute leak tightness in the Saturn S-IVB. In order to obtain (1) minimum distortion, (2) minimum heat input, (3) weld soundness, and (4) adequate mechanical strength, studies are being made to develop the electron beam welding process for this purpose.

4.8.1 Preliminary Tests

Preliminary electron beam weld tests were performed on linear butt welds in Type 347 stainless steel 1/8 inch thick. The maximum temperature gradient was measured transverse to the joint using a temperature sensitive lacquer. Bead on and bead off specimens, prepared from these welds, were tested at room temperature to determine tensile strength.

4.8.2 Results of Preliminary Testing

Figure 4-3 is a graphic representation of the effect of distance from the weld center line on the maximum temperature. Tensile test data are summarized in Table 4-7. Specimens with bead off exhibited the greatest values.

4.8.3 Future Studies

Additional weld tests are in progress to determine the quality of circular joint welds of receptacle to flange, using dollar plates to simulate the receptacle. Efforts are being made to develop satisfactory beam decay and tie-off conditions. Temperature gradient and distortion measurements will be made during these tests. Upon completion cf the above phase of study, a production prototype fixture will be constructed for welding actual sample parts. These welds will be tested for leakage using helium gas. Results of future testing will be presented in a later issue of this report.

EFFECT OF DISTANCE FROM WELD CENTER LINE ON MAXIMUM TEMPERATURE

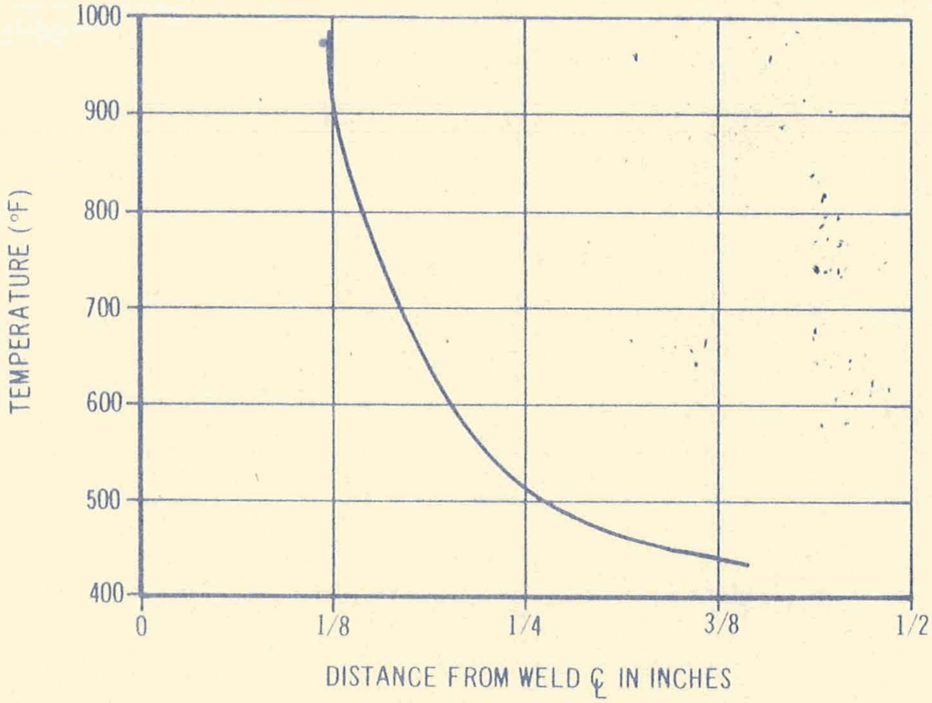


FIGURE 4-3

TABLE 4-7
TENSILE PROPERTIES OF TBF RECEPTACLE WELDS

SPECIMEN* TYPE	AVE. FTY (PSI)	AVE. FTU (PSI)	ELONGATION, IN 1 INCH (%)
BEAD ON	40,600	88,700	30
BEAD OFF	44,300	91,800	35

*15 SPECIMENS OF EACH TYPE WERE TESTED

4.9 DEVELOPMENT OF FLOWSOLDER METHODS

Preliminary development of flowsolder methods for soldering printed circuit wiring boards, with particular emphasis on reduction of the formation of dross, was presented in the last issue of this report. Work is continuing to develop additions and modifications for the flowsolder machine. During the current report period, automatic fluxing and cooling systems were investigated.

4.9.1 Automatic Fluxing

It was postulated that foam fluxing would be the most feasible system for use with the flowsolder machine. A test system was constructed of porous ceramic stones submerged in liquid flux. Air was forced through the porous ceramic to produce a foam wave. The sample wiring board, passed through the top layer of foam, was coated with a thin, even film of flux.

4.9.2 Automatic Cooling

The test cooling system, designed to allow electronic components to cool during the soldering process, consists of a coil submerged in cooling liquid (ethyl alcohol plus dry ice) having temperatures from -60°F to -120°F. An inorganic gas, such as argon or carbon dioxide is passed through the coil and directed to the region approximately 1/2 inch beyond the solder wave. The blast of cooled gas (40°F to 60°F reduces the temperature of the components immediately following the soldering process.

4.9.3 Test Results

4.9.3.1 Automatic Fluxing

Foaming fluxing units using Lonco 5177 rosin base flux (made by London Chemical Co.) gave good results. Flux application, with foam wave height held constant, was completely automatic. The film produced was thin enough for satisfactory drying. The solderability was excellent.

4.9.3.2 Automatic Cooling

Component lead temperatures were recorded both with and without the cooling system in operation. Figure 4-4 is a graphic representation of temperatures without component cooling. The effect of the cooling system on component temperatures is shown graphically in figure 4-5. The peak temperature without component cooling was 355°F. The peak temperature was 330°F with the component cooling system.

4.9.4 Conclusions

Test results indicate that the foaming fluxing unit and the component cooling system will improve the quality of soldered printed wiring boards. The sharp temperature drop shown in figure 4-5 indicates that the cooling system will greatly reduce the probability of component damage from heat shock.

4.9,5 Future Development

Development of the following flowsoldering improvements is planned:

a. Solder blanketing oil

b. Oil blanket recirculating and filtering system

c. Warp retarding board carrier

An evaluation of these developments will be presented in a later issue of this report.

COMPONENT LEAD TEMPERATURES WITHOUT COMPONENT COOLING

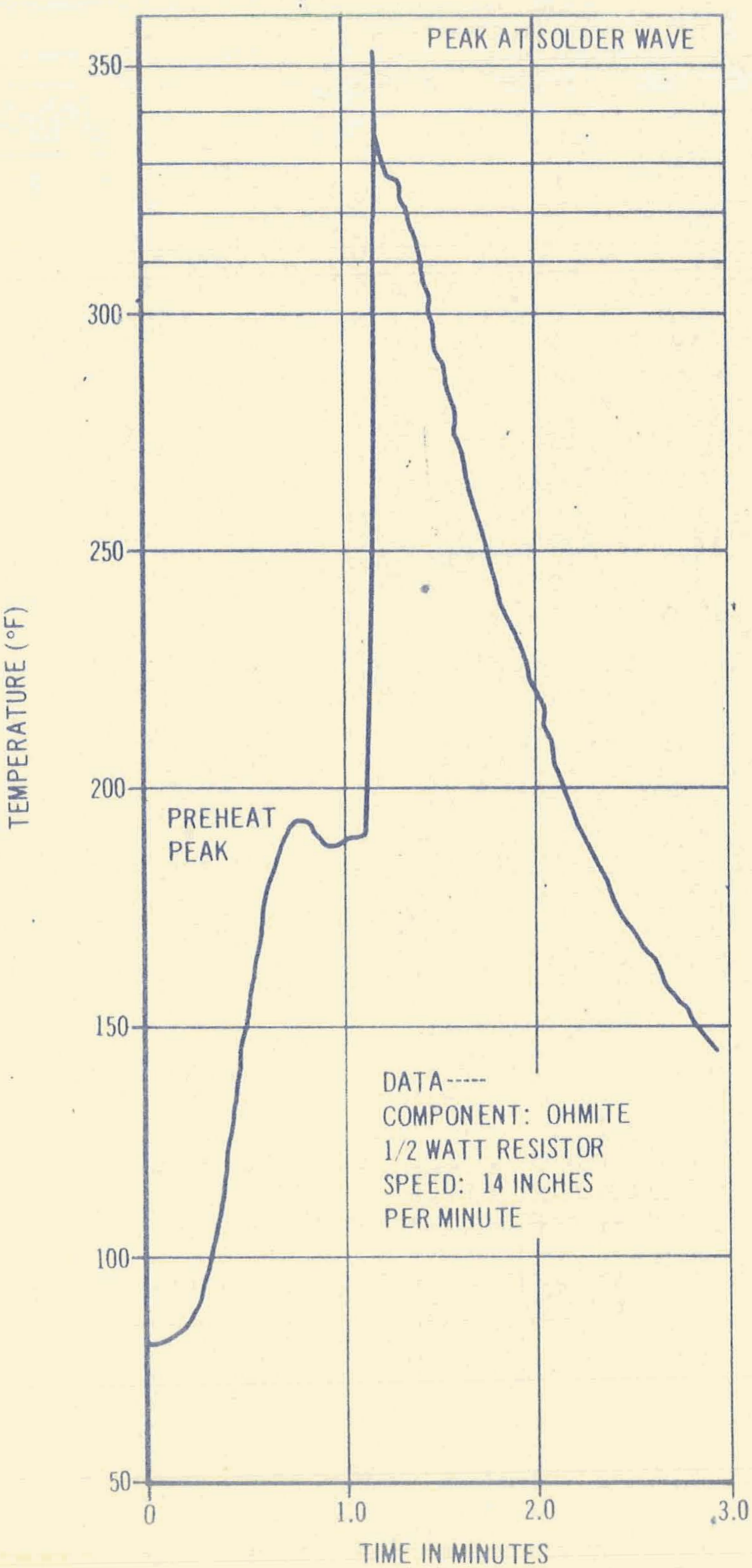


FIGURE 4-4

COMPONENT LEAD TEMPERATURES USING
COMPONENT COOLING SYSTEM

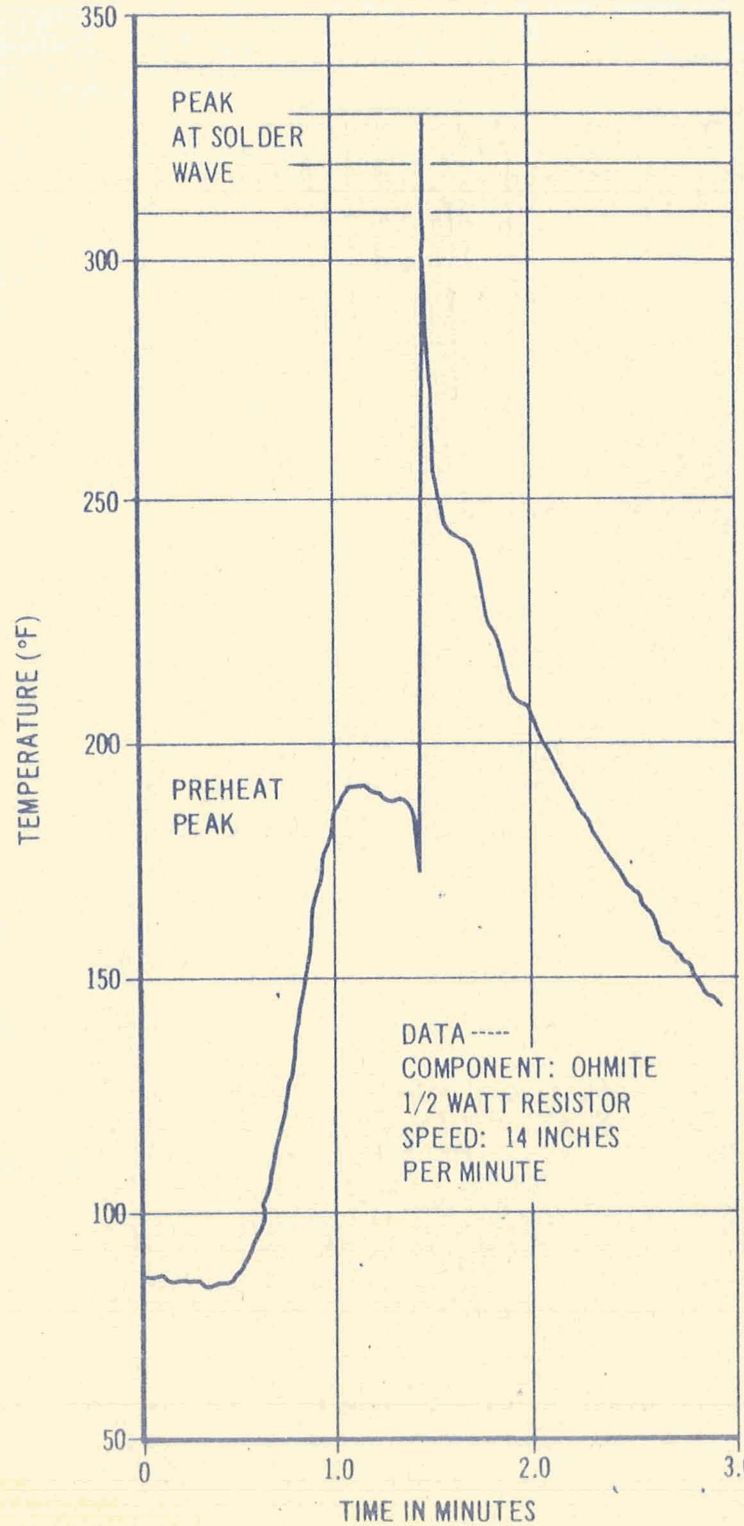


FIGURE 4-5

4.10 IDENTIFICATION OF MOLDED CABLE ASSEMBLIES

A study was initiated during the last report period to determine methods of modifying the machine used to imprint identification marking into Saturn S-IV molded parts, making it suitable for marking molded parts of reduced size in the Saturn S-IVB. The work was completed during the current report period.

4.10.1 Results

The Saturn S-IV stamping machine was modified by (1) reducing the type size from 3/16 inch to 1/8 inch in height to allow a 33 per cent reduction in area and (2) designing a fixture to permit stamping of the inclined surface of conical molded parts.

4.10.2 Conclusion

The Saturn S-IV stamping machine has been successfully modified for use on Saturn S-IVB molded cable assemblies.

4.11 SPRAYER HEAD ASSEMBLY FOR PROPELLANT TANK, WASH AND RINSE SYSTEM

An efficient sprayer system for washing and rinsing the interior of the hydrogen tank is being developed. Earlier studies (see issue six of this report) resulted in the determination of power requirements and approximate operating conditions. The sprayer head configuration is now being developed.

4.11.1 Additional Progress

Tests were conducted at Turco Products, Inc. to establish the feasibility of using two sprayer assemblies mounted on a rotating bar. Good results were obtained with this arrangement. Douglas Aircraft Company has now established the optimum sprayer assembly configuration. A complete sprayer assembly will be constructed and tested at Douglas Aircraft Company facilities located at Huntington Beach, California.

4.12 FABRICATION TECHNIQUE AND NEW DESIGN FOR BULGE FORMING BAG

Improvements in the rubber-to-fabric bond of the bulge forming bag were developed during the last report period (see issue one of this report). During the current report period, a small scale pressure bag was constructed with edge cavities designed to test the salt mandrel method of forming the edge.

4.12.1 Current Progress

The salt mandrel forming method, although feasible, was found to require extensive work in order to eliminate unfavorable aspects. Refinements, developed in the over-all bulge forming system, have permitted simplification of the bag design. Work with the salt mandrel method, as well as the use of fabric in the bag construction, have, therefore, been discontinued.

4.12.2 New Edge Construction

The design refinements of the bulge forming system have made possible the development of a simplified edge construction for the bag; eliminating complicated molded or extruded shapes. A removable, silicone strip is used to form the inside radius of the edge. The thickness of the edge is approximately 3/4 inch. Multiple layers of butyl rubber are used in the bag fabrication.

4.12.3 Conclusion

The new fabrication technique and edge design are apparently quite satisfactory. Experience with the newly designed bag will determine the necessity and course of future development.

4.13 INVESTIGATION OF ALTERNATE CORE TYPES FOR SATURN S-IVB COMMON BULKHEAD

Leakage of liquid hydrogen through the Saturn S-IV common bulkhead meridian welds could cause hydrogen to be trapped within the honeycomb core material. In anticipation of the possible occurrence of this problem in the Saturn S-IVB common bulkhead, cores designed to allow a free flow of hydrogen are being developed.

4.13.1 Preliminary Work

4.13.1.1 Core Samples

Preliminary tests were performed to determine the suitability of the following core types:

a. Vented core: Heat resistant phenolic (HRP) honeycomb, 3/16 inch cell, 1 inch thick

b. Crushed core: 3/16 inch cell, HRP core crush-overlap bonded to thickness of 1 inch

Cells of the vented core samples were drilled with two rows of 1/16 inch diameter holes approximately 3/8 inch on centers in each row. Crushed core samples were prepared by bonding together two pieces of core with a 1/4 inch crushed overlap splice to an over-all thickness of one inch.

4.13.1.2 Initial Results

The crushed core type proved to have an excessively high density to strength ratio. The density was nearly twice that of the vented core.

4.14.2 Test Criteria

Criteria for the determination of optimum weld parameters will be based on visual, radiographic, and dye-penetrant inspections as well as mechanical testing of welds. Test welds will be made at selected conditions to determine reproducibility and consistency.

4.14.3 Future Work

The optimum settings developed by laboratory studies will be tested on full size, simulated production joints using production tooling. Results obtained from the production weld parameter studies will be presented in a later issue of this report.

4.14 INVESTIGATION OF MIG PRODUCTION WELD PARAMETERS

In order to improve Saturn production welding operations and upgrade hardware quality, a program was initiated to determine optimum production welding parameters. Acceptable tolerances in weld parameters and optimum machine settings for production welding are needed.

4.14.1 Test Program

Tests will be conducted to establish optimum weld settings for each of the following production weld joints:

a. Liquid oxygen tank assembly

b. Forward common bulkhead meridian

c. Aft common bulkhead meridian

d. Forward dome meridian

e. Aft dome meridian

f. Dollar weld

Tests will be performed to determine optimum weld heat settings including (1) welding current, (2) arc voltage, and (3) weld speed. Because of varying material thickness in production weld joints, these parameters will establish only basic welding conditions.

Additional tests will be conducted at the basic settings developed above to study the effects of such fixed parameters as (1) torch angle, (2) gas flow rate, (3) nozzle size, (4) torch-to-work distance, and (5) wire diameter.

SECTION V

PROTECTIVE PACKAGING

Work accomplished toward the development and improvement of protective packaging procedures for the Saturn S-IVB and associated items is summarized in this section.

5.1 ENVIRONMENTAL PROTECTIVE COVERS

An environmental cover is required for use as a protective device over the Saturn S-IVB stage. The cover material must be capable of resisting abrasion, tension on seams, and varying weather conditions. An investigation is being made in order to find a suitable material for this purpose.

5.1.1 Initial Work

Preliminary work indicates that neoprene coated, two-ply nylon fabric is the most suitable material for an environmental cover. Three-ply fabrics are too heavy for this application and one-ply construction does not provide the necessary protection. Neoprene coated, two-ply nylon fabrics, from E. I. du Pont and from Chemical Rubber Products, were selected and are being subjected to laboratory tests to determine if the physical properties of these materials are adequate for the intended purpose.